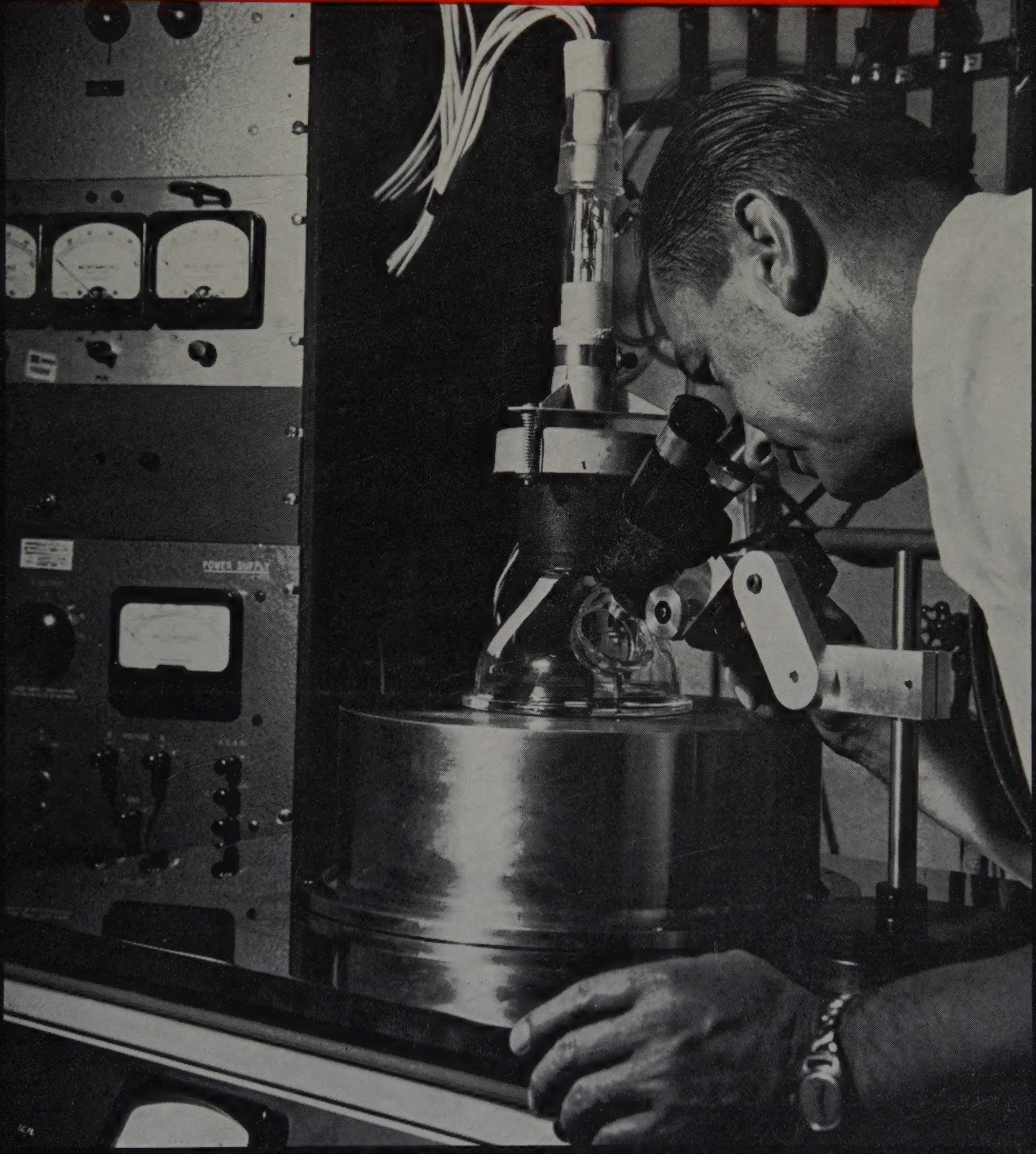
October 1961

75¢

SEMICONDUCTOR PRODUCTS

R&D • DESIGN • TECHNOLOGY • APPLICATIONS



Electron Beam Fabricates Semiconductor Devices

R. F. Heating in Crystal Growing

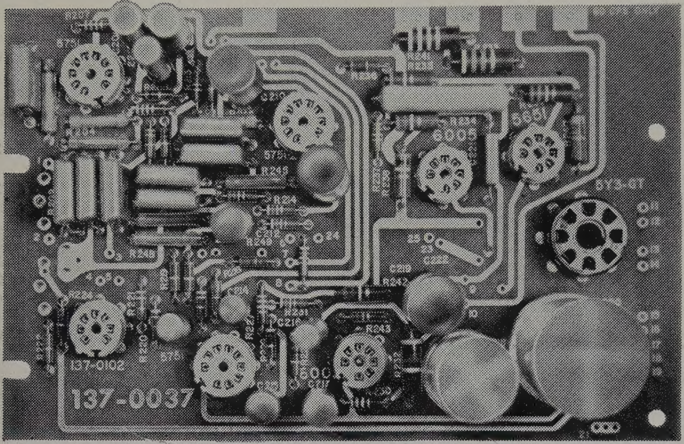
A Solid State 125 Watt Linear Power Amplifier

High Speed Circuit Breakers

Gain Control in Audio Amplifiers

2 Electronic Plating Tips you can profit from!

You know B&A® Metal Fluoborates speed plating at lower costs. Now here are some other advantages you shouldn't overlook.

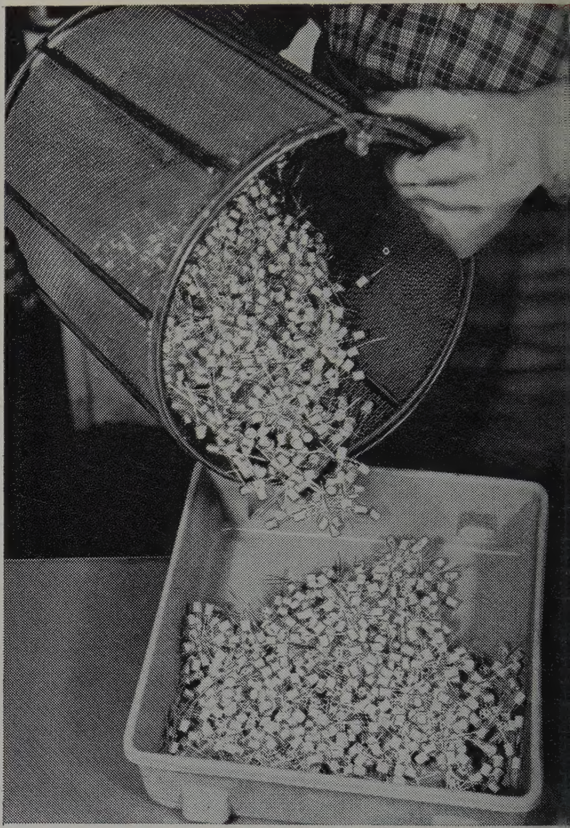


B&A Fluoborates Improve Printed Circuits . . . Need an effective stop-off for etching? Use a lead-tin alloy from B&A fluoborate solutions. The deposit is readily soldered even after plated part has been stored for a long time—and more reliable assembly results.

☐ Plated wiring calls for B&A copper fluoborate. It gives high speed deposition, with minimum maintenance and control problems.

☐ An active undercoat for precious metal deposits in printed circuits is nickel from B&A nickel fluoborate. The bath is simple to prepare and maintain, is stable, offers excellent control.

B&A Metal Fluoborates come in concentrated solution form. Baths made from these fluoborates have excellent stability, are easily maintained . . . have good covering power . . . give fine-grained deposits of good color. For technical data as it applies to your application, just drop us a note, or ask to have a B&A representative call.



Tin-Plated Semiconductor Components . . . T fluoborate baths are used to plate semiconduct components—not only for high plating rate but to improve reliability during assembly well. Reason: *Tin deposited from B&A fluobo ate solutions is readily soldered.* Plating is eas too. The bath is practically self-sustaining, operated at room temperature, and control simple. In deposits where a lower melting poi is desired, a lead-tin alloy is used. For othe electronics applications, B&A cadmium fluo borate and indium fluoborate offer similar a vantages to those listed above.

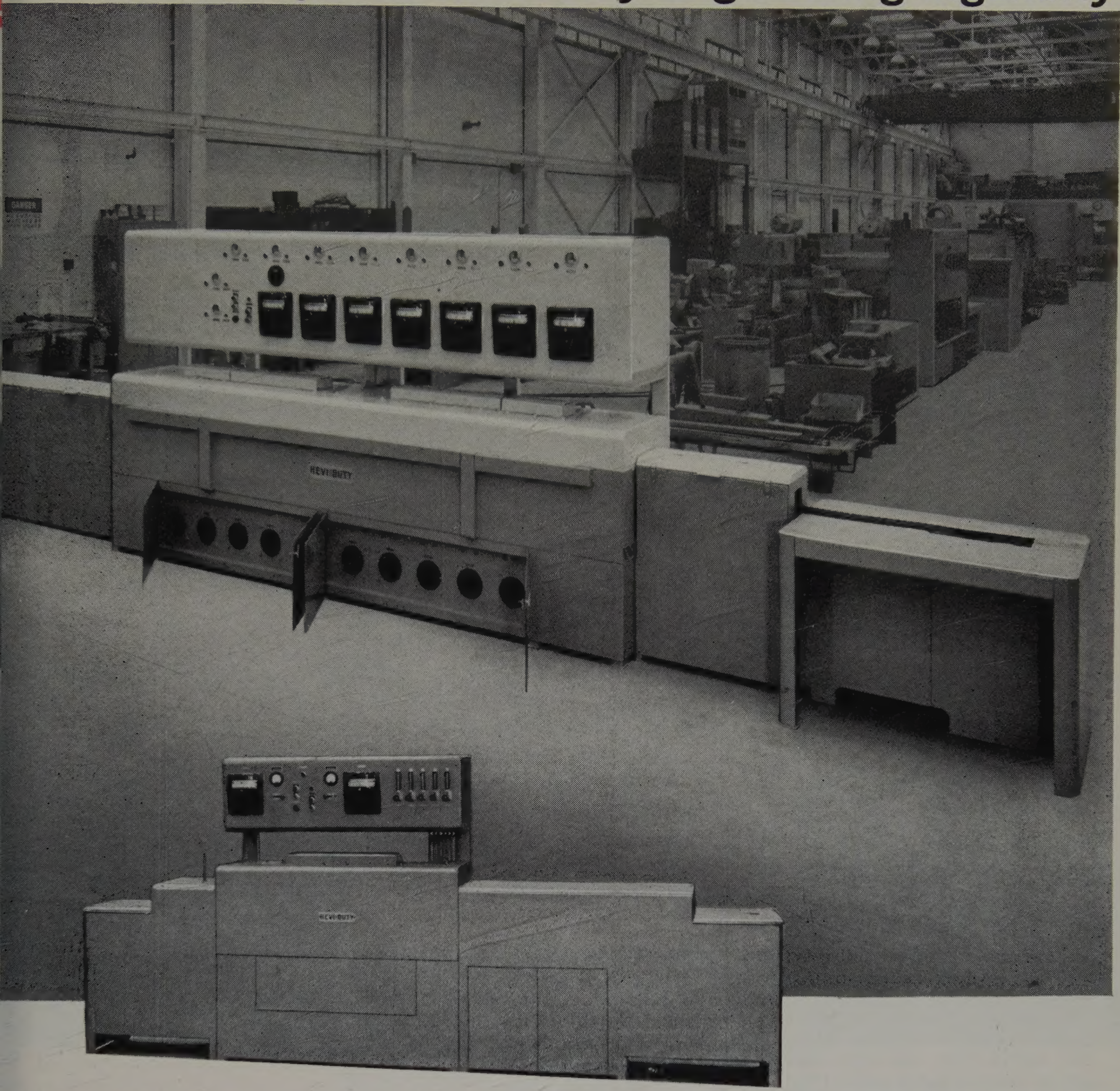
BAKER & ADAMSON®
Plating Chemicals

Allied Chemical

GENERAL CHEMICAL DIVISION
40 Rector Street, New York 6, N. Y.

Circle No. 1 on Reader Service Card

Another example of Hevi-Duty Engineering Ingenuity



New conveyor furnaces feature smooth, vibration-free belt travel to improve quality, reduce rejects

eaturing a shock-mounted conveyor drive and a spe-ally designed electronic speed control system, these ew furnaces from Hevi-Duty promise greater yield r the semiconductor industry.

The new Hevi-Duty conveyor furnaces are attrac-vely styled to fit into a modern production setting.

On the large unit, designed for alloying, controls are nveniently grouped for each zone. The seven pyrom-ers which provide automatic temperature control are ounted at eye level. Power controls are neatly recessed the base and protected by doors to prevent accidental sturbance of power settings.

The unit operates up to 1000°C, has ten control zones d is equipped with nitrogen end caps. These end caps arantee minimum hydrogen requirement for low dew-int and eliminate hydrogen flame around the work.

The smaller furnace below is designed for soldering and alloying. This unit operates to 1000°C with four circuits and has four variable transformers regulated by two saturable core reactor systems.

Get full information about these furnaces or other Hevi-Duty batch or automatic furnaces for semicon-ductor heat processing needs: reduction and casting, diffusion, melting, oxidizing, deposition, alloying, soldering, decarburizing, glassing. Call your Hevi-Duty sales engineer or write to Hevi-Duty, Watertown, Wis.

H-30-61

HEVI-DUTY

Electric and Fuel-Fired Industrial Furnaces and Ovens

BP C

Hevi-Duty Electric Company, Watertown, Wis.
A Division of Basic Products Corporation

Circle No. 5 on Reader Service Card

SEMICONDUCTOR PRODUCTS

SANFORD R. COWAN, Publisher

October 1961 Vol. 4 No. 10

CONTENTS

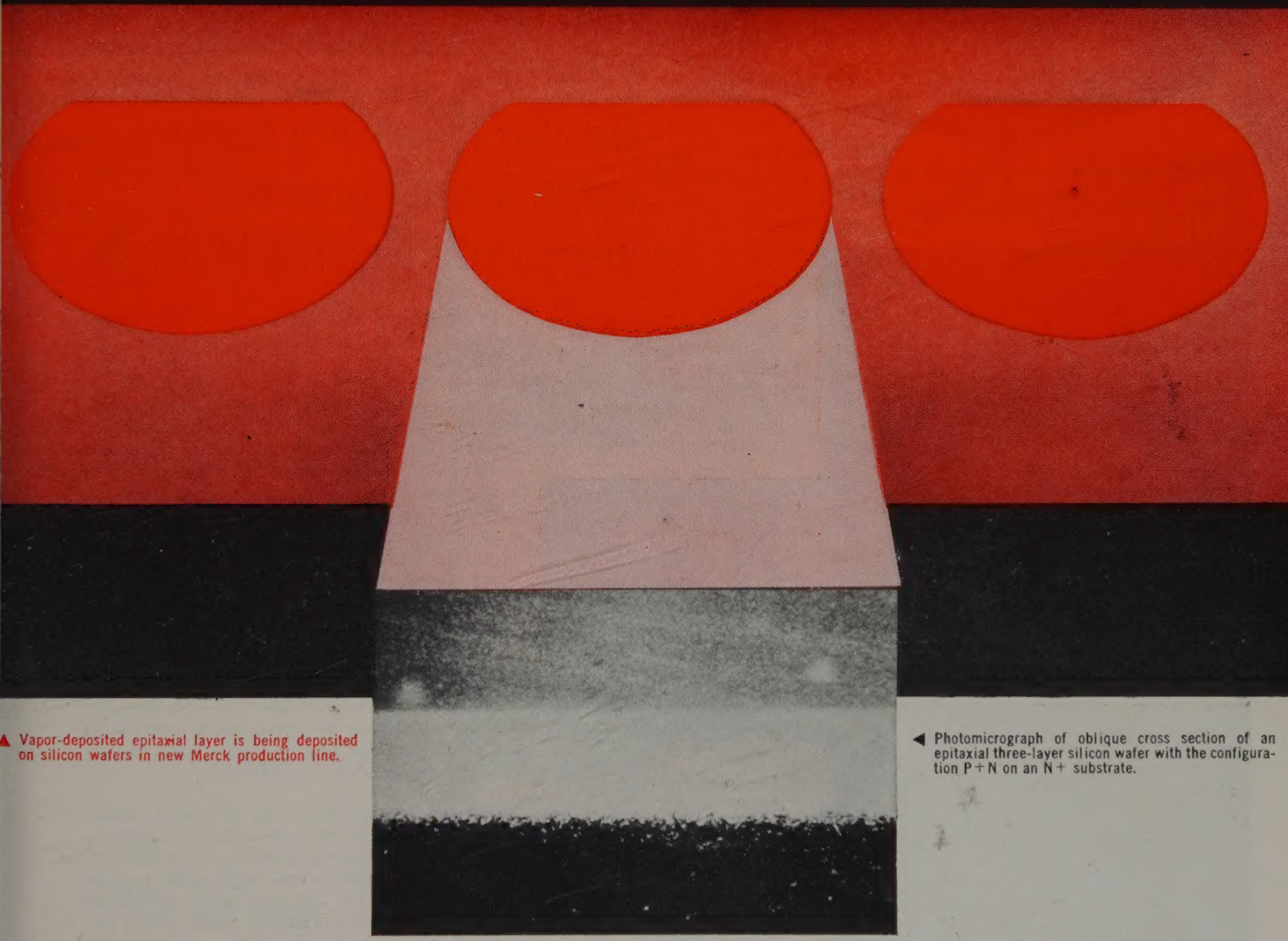
SEMICONDUCTOR PRODUCTS assumes no responsibility for company credit affiliations claimed by authors for byline purposes.

Front Cover

Electron beam processing holds promise as a technique for fabricating semiconductor devices, according to Dr. Wolfgang W. Gaertner, Vice President, Solid State Physics Branch at CBS Laboratories. The fabrication of a novel microjunction diode demonstrates that electron beams and ion beams can be used to form aluminum-silicon junctions with excellent electrical characteristics. In the process thin metal films are deposited under vacuum in controlled thicknesses from 2,000 angstroms (approximately 254,000ths of an inch) to 2 microns (10,000 times larger, or roughly 25,000ths of an inch).

vapor-deposited Epitaxial Silicon Wafers on stream at New Merck Plant

production quantities available from pioneer in hyper-pure silicon



▲ Vapor-deposited epitaxial layer is being deposited on silicon wafers in new Merck production line.

◀ Photomicrograph of oblique cross section of an epitaxial three-layer silicon wafer with the configuration P+N on an N+ substrate.

For improved device characteristics you can rely on Merck Epitaxial Wafers with their superior surface finish, precise layer thickness control and uniform resistivity profile. You can also reduce saturation voltage and improve switching characteristics. Device potential is practically unlimited.

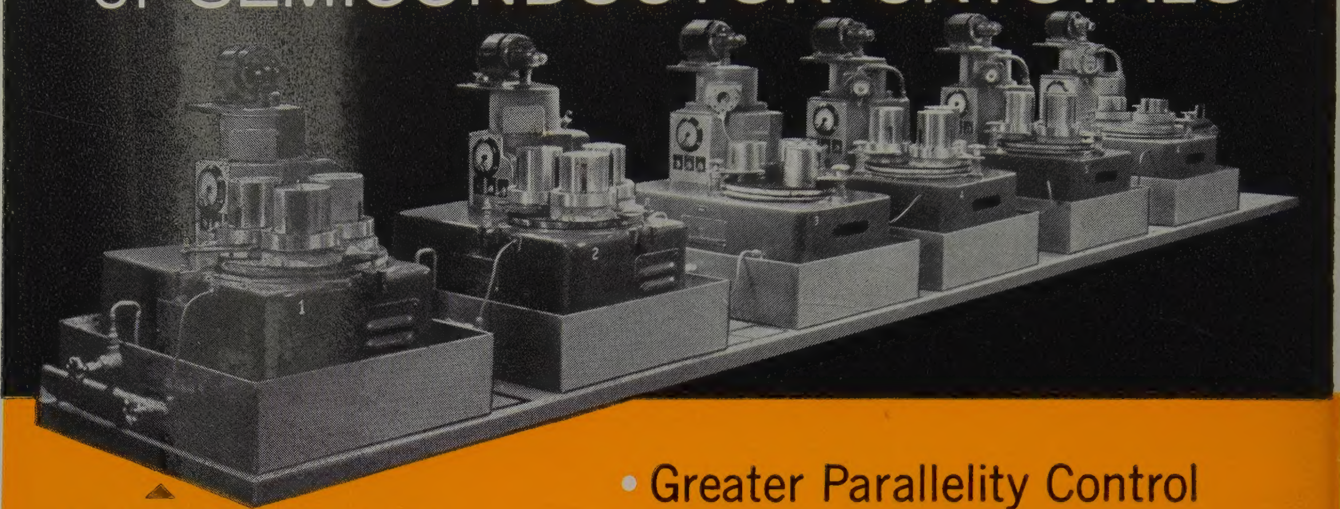
There's no need to wait for these benefits. Merck Epitaxial Silicon Wafers in production quantities are immediately available in N^+N and P^+P configurations. For details write, wire or phone today.

Electronic Chemicals Division
MERCK & CO., Inc. • RAHWAY, NEW JERSEY

RESEARCH and PRODUCTION FOR BETTER SOLID-STATE MATERIALS

Circle No. 7 on Reader Service Card

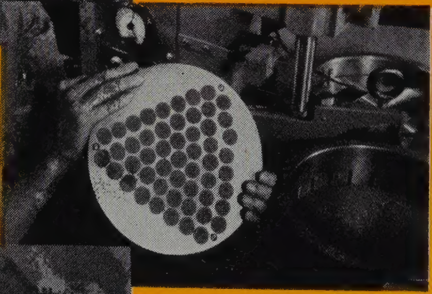
What's new in
LAPPING and POLISHING of SEMICONDUCTOR CRYSTALS



Texas Instruments Incorporated meets critical specifications in wafer production by lapping and polishing on these and other Lapmasters.

- Greater Parallelity Control
- Scratch-free Surfaces
- Improved Polishing Methods

Special fixture with adjustable diamond stop points guarantees lapping crystals to exact predetermined size and parallelity. It is only necessary to lap one face of the wafer flat prior to mounting.



Diamond fixtures are also available for Lapmaster Model 24 where production warrants it.

Free lapping provides excellent results where thickness and parallelity specifications do not exceed .0002″ and are .008″ or thicker. At Fansteel Metallurgical Corporation, Model 12 Lapmasters are used with special plates to achieve an extremely fine finish.

From the very beginning of the semiconductor industry, the Lapmaster has played an important part in achieving the parallelity, finish and critical size of wafers so necessary for reliable semiconductor performance. In fact, Lapmasters were used in the earliest laboratory experiments on semiconductors. Since then, Lapmaster engineers have continued to work hand-in-hand with semiconductor manufacturers in developing new lapping and polishing techniques to meet changing production and quality control requirements.

Over 100 semiconductor manufacturers now operate batteries of these machines—around the clock in many cases. Lapmasters are relied upon to consistently produce silicon or germanium wafers to size as thin as one mil and with parallelity tolerances to .000050″.

Our wide experience in this and other fields can help you find the answers to your wafer lapping problems. Lapmaster Division engineers will work with you in developing the lapping and polishing technique that's exactly right for your particular specifications.

A few of the many new and improved techniques that work for others are shown here—contact us for more information. Request Bulletin L-450 for general information.

Lapmaster ...THE MACHINE THAT PUT PRECISION LAPPING ON A PRODUCTION BASIS

A product of

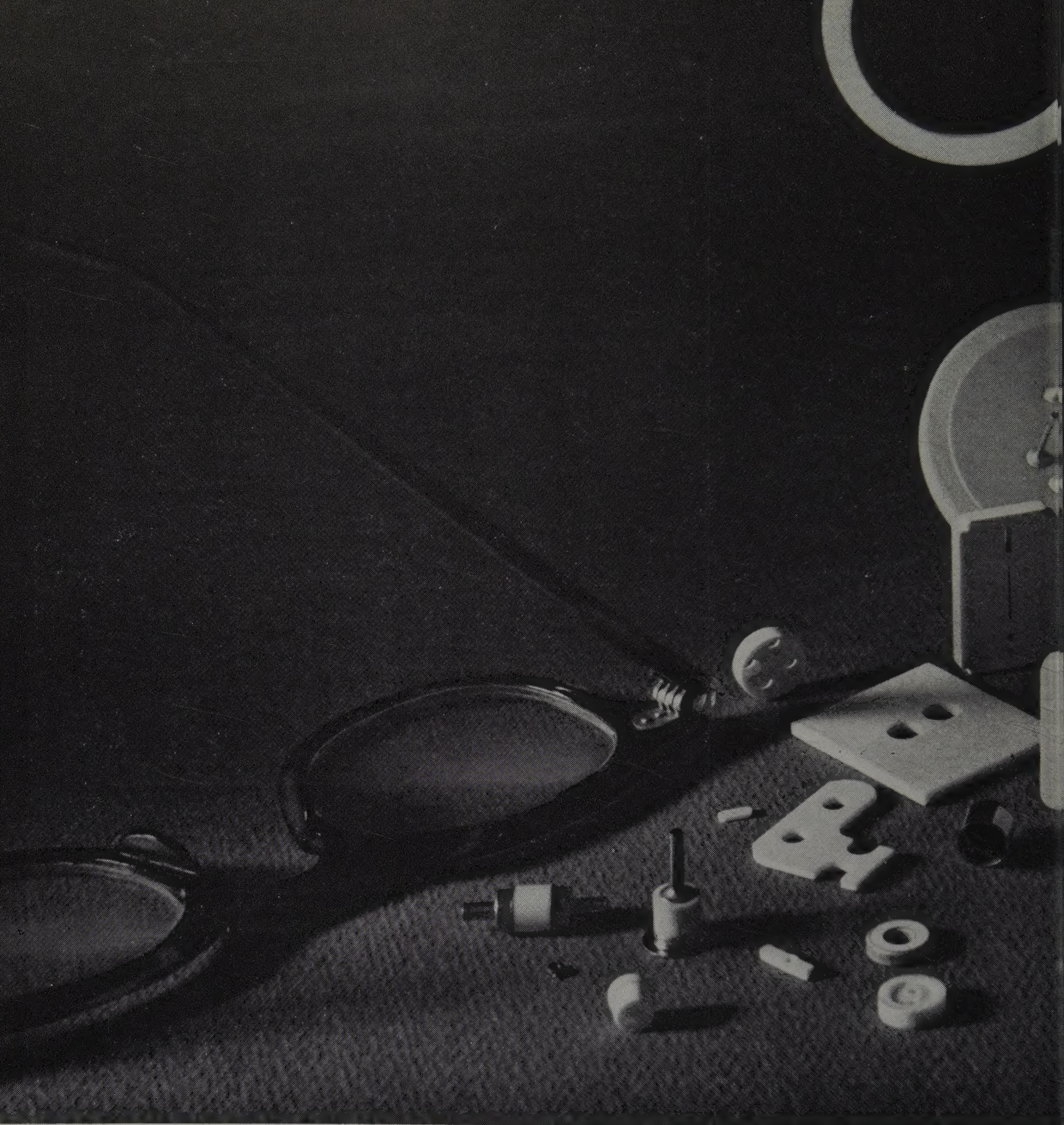
CRANE PACKING COMPANY
6493 Oakton St., Morton Grove, Ill. (Chicago Suburb)
In Canada: Crane Packing Company, Ltd., Hamilton, Ont.
In England: Payne Products International, Slough Bucks

Circle No. 8 on Reader Service Card

Semiconductor Products

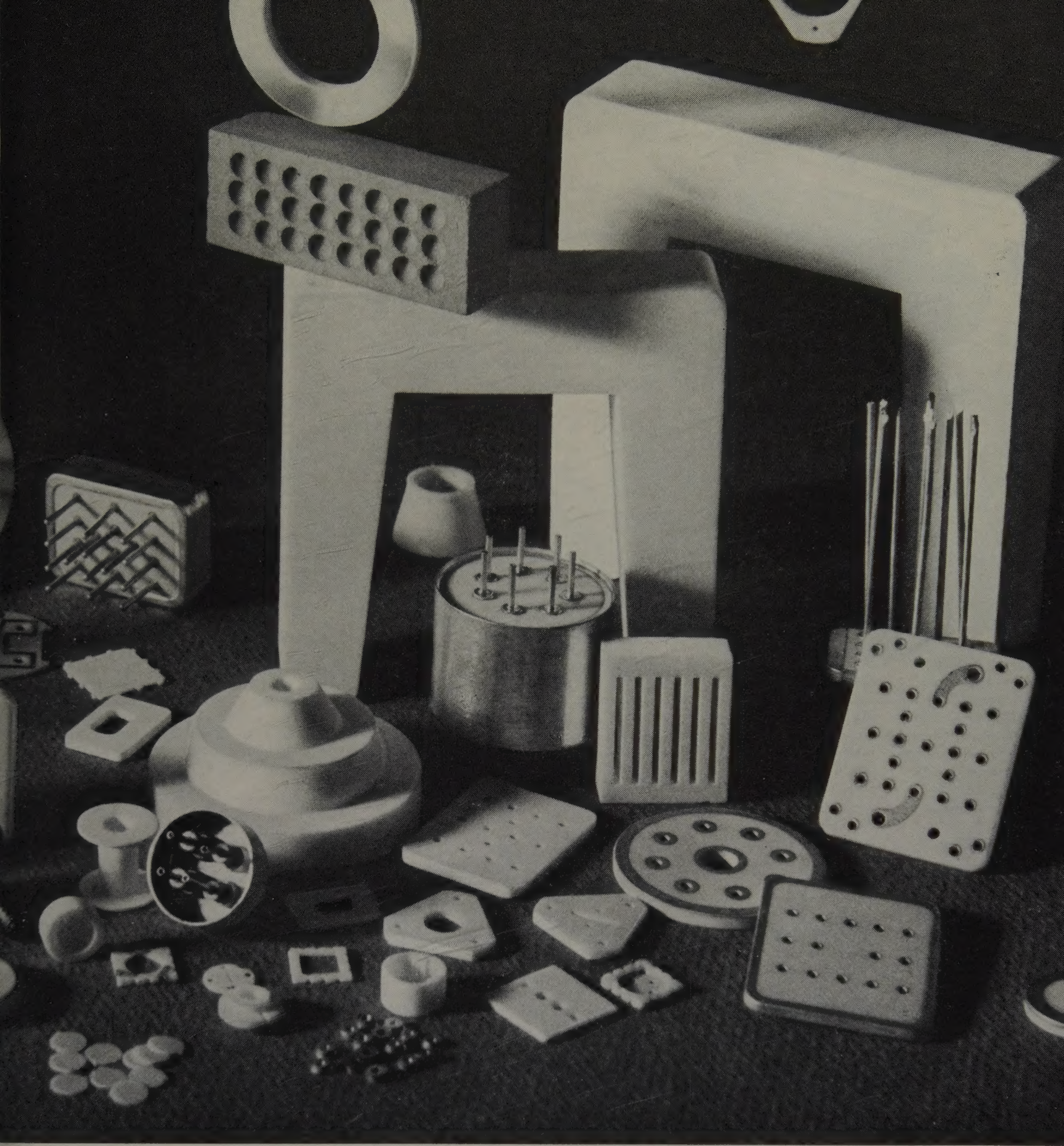
SEMICONDUCTOR PRODUCTS is published monthly by Cowan Publishing Corp., Executive and Editorial Offices: 300 West 43rd Street, New York 36, N. Y. Telephone JUdson 2-4460. Known office of Publication 50 Emmett Street, Bristol, Connecticut. Subscription price $6.00 for 12 issues in the United States, U.S. Possessions, APO & FPO, Canada and Mexico. All other countries $10.00 for 12 issues. Single copy 75¢. Direct all correspondence to N. Y. office. Second Class Postage Paid at Bristol, Connecticut. Copyright 1961 by Cowan Publishing Corp.

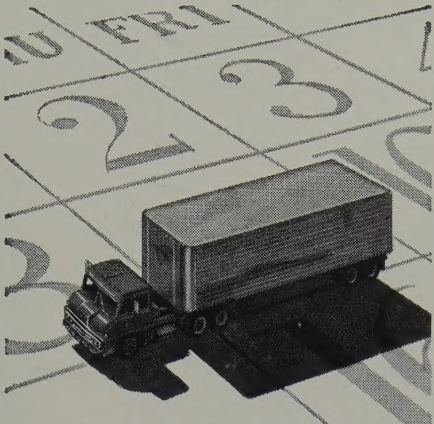
POSTMASTER: SEND FORM 3579 to SEMICONDUCTOR PRODUCTS, 300 West 43rd STREET, NEW YORK 36, N. Y.



20/20 imaginatio

HIGH TEMPERATURE CERAMICS • GLASS-METAL SEALS • METALLIZED PARTS • CERAMIC SEALS AND HEADERS • MICROMINIATURE SUBSTRA





Current Books

Electromechanical System Theory by Herman E. Koenig & William A. Blackwell. McGraw-Hill Book Company, Inc., New York, N.Y. $14.50. The development presents an orderly operational procedure for deriving mathematically the characteristics of systems of components from a knowledge of the component characteristics and their prescribed mode of interconnection.

Elements of Electronics by Henry V. Hickey and William W. Villnes. Second edition. McGraw-Hill Book Company, Inc., New York, N.Y. $8.75. A complete, well-rounded, basic background for everyone interested in television, radar, and sonar.

Thermoelectricity: Science and Engineering by Robert R. Heikes and Roland W. Ure, Jr. Interscience Publishers, New York, N.Y. $18.50. This book covers the physics and chemistry of thermoelectric materials, the design of materials, and the device technology.

Electronic Engineer's Reference Book edited by L. E. C. Hughes. Second edition. The Macmillan Company, New York, N.Y. $18.00. This reference book endeavors to put before engineers in industry and in development laboratories some of the latest knowledge and techniques in the electronics field which might not be easily available to them.

Time Relays by G. V. Druzhinin. Pergamon Press, New York, N.Y. $2.50. Intended for wide circles of engineers and technologists who work in the field of industrial automation.

Iterative Arrays of Logical Circuits by Frederick C. Hennie III. M.I.T. Press, Cambridge, Mass. and John Wiley & Sons, Inc., New York, N.Y. $4.95. This book is written for persons working in the communications sciences, and is especially pertinent to the areas of information processing, switching theory, and computer design.

Semiconducting III-V Compounds by C. Hilsum and A. C. Rose-Innes. Pergamon Press, New York, N.Y. $10.00. It deals with the band structure, crystal structure, preparatory techniques, transport processes, optical absorption, photoelectric effects and galvano-magnetic properties, as well as with a number of device applications.

Electrical Principles of Electronics bv Angelo C. Gillie. McGraw-Hill Book Company, Inc., New York, N.Y. $10.00. Here is a clear, precise explanation of the fundamental laws and principles of electricity for radio-television repairmen, electricians, homeowners, and anyone interested in electricity and the way it works.

High-Frequency Magnetic Materials by W. J. Polydoroff. John Wiley & Sons, Inc., New York, N.Y. $9.00. This book is a comprehensive guide to ferromagnetic materials and their applications at high frequencies.

Semiconductor-Diode Parametric Amplifiers by Lawrence A. Blackwell and Kenneth L. Kotzebue. Prentice-Hall Inc., Englewood Cliffs, N.J. $9.00. A theoretical treatment and discussion of parametric devices showing how and why they work, and when they can be used to best advantage.

The Handbook of Thermophysical Properties of Solid Materials edited by Goldsmith, Waterman & Hirschorn. Published by special arrangement with U.S. Air Force. The Macmillan Company, New York, N.Y. $90.00. 5 volumes cover elements, alloys, ceramics, cermets, and includes a list of references.

Proceedings of the National Electronics Conference, Vol. XVI. National Electronics Conference, Inc., Chicago, Ill. $6.00. Papers covered include solid state devices and circuits; microelectronics; parametric devices and techniques; transistor circuit applications; and solid state circuits.

High Frequency Applications of Ferrites by J. Roberts. D. Van Nostrand Company, Inc., Princeton, N.J. $4.85. This book is intended primarily for advanced students of Electrical Engineering and Physics, and those engaged in the design or operation of electronic equipment.

Introduction to Electrical Engineering Science by Harold A. Foecke. Prentice-Hall, Inc., Englewood Cliffs, N.J. $15.65. An integrated, analytical approach providing a rigorous, versatile base for study in any more specialized area of electrical engineering.

The Physical Theory of Transistors by Leopoldo B. Valdes. McGraw-Hill Book Company, Inc., New York, N.Y. $10.50. This text analyzes the flow of current through semiconductor materials and derives relationships between the electrical characteristics of transistors and their physical structure.

Dictionary of Mechanical Engineering by Alfred del Vecchio. Philosophical Library, New York, N.Y. $6.00. This comprehensive dictionary and sourcebook presents prime definitions in the fields of architecture, automatic controls, engineering mechanics, fuels and combustion, power plants, along with related definitions in the field of basic electricity, heat treatment of metals, basic mathematics and welding.

British Miniature Electronic Components and Assemblies Data Annual 1961-62; Edited by G. W. A. Dummer and J. Mackenzie Robertson. Pergamon Press, New York, N.Y. $15.00. This is the first volume in an important new annual series and contains essential data in concise form on a wide range of miniature components, and information on the effect of potting resins, shock and vibration, and temperature overload.

Vacuum Technology Transactions; Edited by C. Robert Meissner. Pergamon Press, New York, N.Y. $17.50. Proceedings of the sixth national symposium.

CHEMICAL USERS KNOW

what a difference a day makes

...PARTICULARLY THE DECISION-MAKERS IN THE ELECTRONIC INDUSTRY. In no other industry are processing problems more complex, quality standards more demanding. Production chemicals *must* meet your specifications, *must* be shipped on time.

SAME DAY SHIPMENT OF HIGHEST PURITY ELECTRONIC CHEMICALS. The J. T. Baker electronic chemicals offer you the highest standards of purity and most precise labeling in the industry. J. T. Baker ships more than 90% of all orders the *same day* they're received. We keep our inventories high so you can keep yours low.

ACTUAL LOT ANALYSIS ON LABEL. Every 'Baker Analyzed' Reagent is labeled with an Actual Lot Analysis that defines purity to the decimal, more than 300 also with an Actual Lot Assay.

Highest purity . . . most precise labeling . . . same-day shipment. Surely three good reasons to discuss your requirements with J. T. Baker Co., Phillipsburg, N. J. See list of electronic chemicals on opposite page.

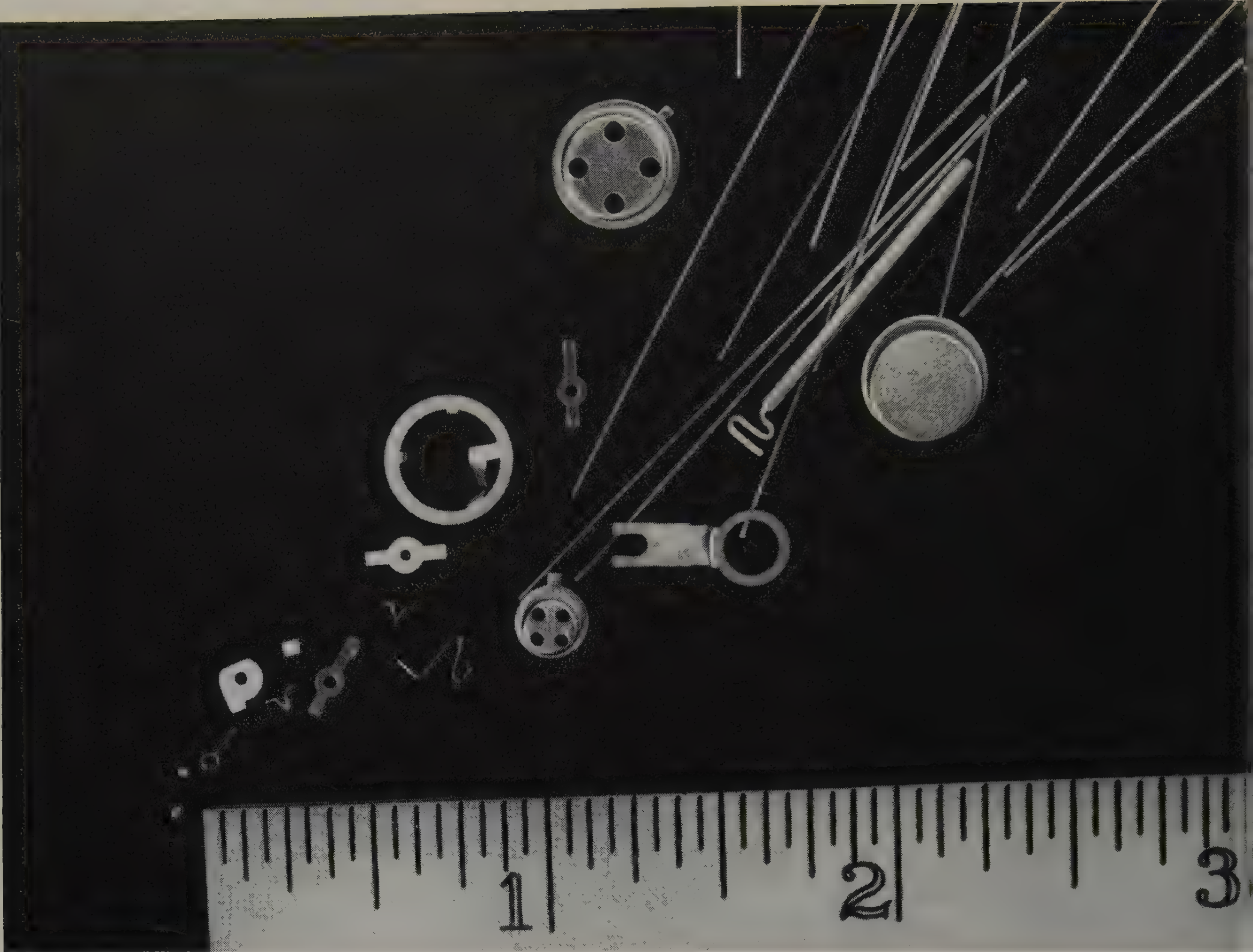
THE ELECTRONIC CHEMICAL USER BUYS MANY VALUES TO PLEASE MANY MEN

. . . he knows that bidding to specifications is only one measurement—he measures all the values. For example, when he buys chemicals he knows a precise definition of purity helps the Electronic Engineer. For the Plant Superintendent, consistently high quality means fewer variables and fewer rejections. For the Production Manager, fast on-time deliveries are important. Which values help the Quality Control Chief? the Cost Accountant?

The electronic chemical user knows! It's the reason J. T. Baker is preferred.

J.T.Baker CHEMICAL **J. T. Baker Electronic Chemicals**

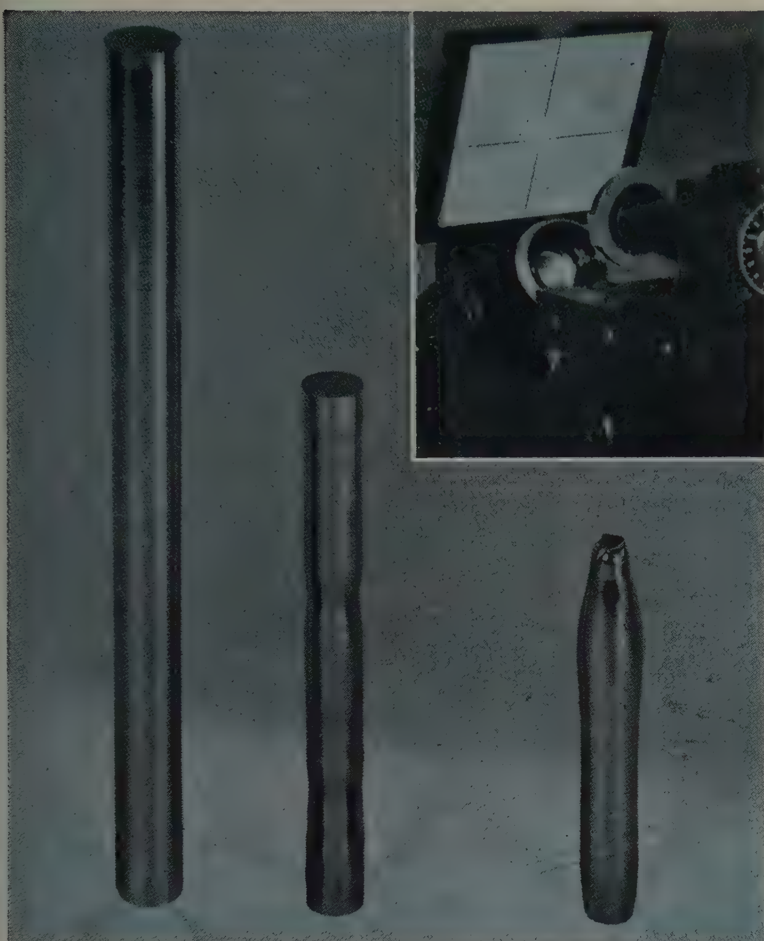
Circle No. 12 on Reader Service Card


1
2
3

SILICON NEWS from Dow Corning

Need 1-0-0 Silicon?

Specify float zoned crystals for these three reasons...



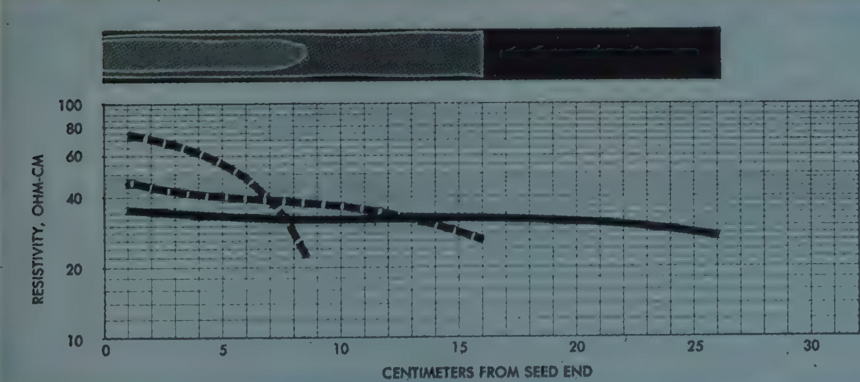
You will find Dow Corning Hyper-Pure (1 0 0) crystals provide a number of definite advantages over Czochralski pulled crystals with (1 0 0) orientation.

More Uniform Dimensions. With Dow Corning vacuum float-zoned (1 0 0) crystals, you get more than twice the useable length of the usual Czochralski crystal . . . better than 50% more than the best premium Czochralski crystal. Physical profile is far more uniform, so wafers have more consistent physical dimensions. Result: crystals that are easier to process . . . less waste.

More Uniform Parameters. Lateral and radial parameters are more uniform throughout the entire length of Dow Corning vacuum float-zoned (1 0 0) crystals. Typical resistivity curves show float-zoned crystals vary less from end to end—and the ends are up to three times further apart. This consistent quality — plus uniformity from rod to rod — means fewer rejects . . . increased device yield.

Ease of Handling. For the clean cleavage and nearly waste-free handling of (1 0 0) oriented silicon crystals, plus the advantages of uniform dimensions and uniform parameters, specify Dow Corning crystals. Greater length means less chance for contamination, less waste and easier handling in scribing and scoring wafers.

Whatever your need — float-zoned crystals of (1 0 0) orientation; crystals of (1 1 1) orientation; doped to specification or high resistivity rod; polycrystalline rod or prepackaged one-piece crucible charges — Dow Corning should lead your list of sources.



Length:	50 mm to 250 mm (approx. 2″ to 12″)
Diameter:	12 mm to 20 mm (.5″ to .79″)
Diameter Variation:	less than 1 mm (.040″)
Type:	P or N
Resistivity:	1 to greater than 1000

For free brochure — "Hyper-Pure Silicon for Semiconductor Devices" write Dept. 1822

Dow Corning CORPORATION

HYPER-PURE SILICON DIVISION • HEMLOCK, MICHIGAN

Circle No. 14 on Reader Service Card

Looking for a compact 1 to 10 watt Germanium Power Transistor with this kind of top level performance?

ACTUAL SIZE

Top reliability is built into each Honeywell transistor. Vacuum baked, given rigorous life and dynamic tests, each is enclosed in a new cold-welded miniature case with threaded mounting stud.

Designed for general use, the Honeywell 2N1658 and 2N1659 are ideal for servo amplifiers, relay drivers, high power unit driver stages, and as medium power switches. Measuring only 0.35 inches in diameter, they handle one to ten watts!

You'll want data sheets, including characteristic curves and servo amplifier circuit diagram, for your files. Fill out and mail the coupon today!

- *Leakage*—I_{CBO} less than 0.5 ma at 80v, 2N1658—60v, 2N1659
- *Saturation voltage*—$V_{CE\ (SAT)}$ less than 0.25v
- *Floating potential*—V_{EBF} less than 0.25v
- *Thermal resistance*—$\Theta_{J\text{-}MB}$ 5° C/watt max. (T_J max., 100° C)
- *Gain*—h_{FE} 30 min @ 0.2 amp; h_{FE} 20 min @ 1.0 amp
- *Frequency response*—500 kc minimum gain bandwidth product
- *Power dissipation*—15 watts at 25° C, 6 watts at 70° C

MINNEAPOLIS-HONEYWELL REGULATOR CO.
SEMICONDUCTOR DIV. • MINNEAPOLIS 8, MINN.

Yes, send me bulletins on the new Honeywell 2N1658 and 2N1659.

NAME ____________________

FIRM ____________________

ADDRESS ____________________

CITY ____________________ ZONE ________

STATE ____________________ PHONE ________

(4)

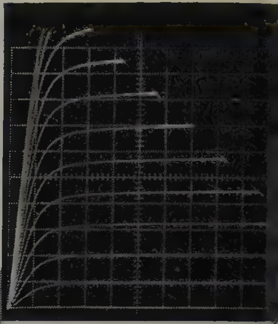
Honeywell

H HONEYWELL Semiconductor Products

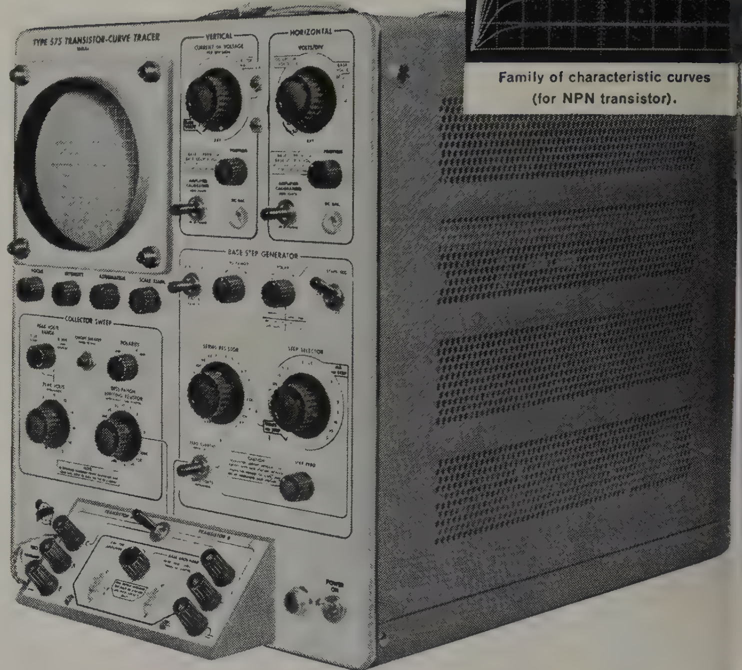
Circle No. 15 on Reader Service Card

TEKTRONIX TRANSISTOR-CURVE TRACER

INVALUABLE TOOL FOR EVALUATING SEMICONDUCTOR DEVICES



Family of characteristic curves (for NPN transistor).



The Type 575 provides 20-ampere collector displays (10-ampere average supply current), two ranges of collector supply (0 to 20 volts, 0 to 200 volts), and 2.4-ampere base supply (positive or negative base stepping).

With a Type 575, you can plot and measure 7 different transistor characteristics. You can display 4 to 12 curves per family—with input current from 1 microampere/step to 200 milliamperes/step or input voltage from 10 millivolts/step to 200 millivolts/step—in repetitive or single-family presentations. You can select either common-emitter or common-base configurations.

Add a Type 175 Adapter and you extend the range of collector displays 10 times and the range of base supply 5 times.

You can also test diodes under a wide variety of conditions and observe waveform characteristics on the 5-inch crt with a high degree of accuracy.

Type 575 Calibrated Displays

Vertical Axis—Collector Current, 16 steps from 0.01 ma/div to 1000 ma/div. Pushbuttons are provided for multiplying each current step by 2 and dividing by 10, increasing the current range to 0.001 ma/div to 2000 ma/div.

Horizontal Axis—Collector Voltage, 11 steps from 0.01 v/div to 20 v/div.

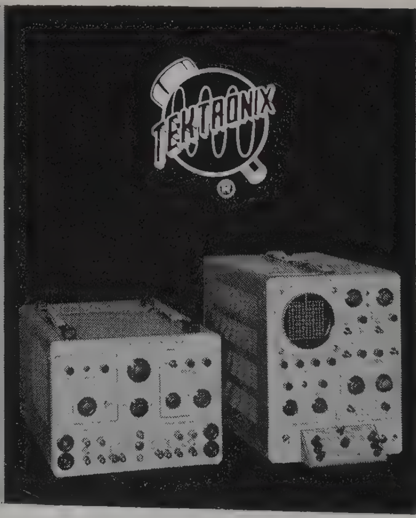
Both Axes—Base Voltage, 6 steps from 0.01 v/div to 0.5 v/div. Base Current, 17 steps from 0.001 ma/div to 200 ma/div. Base Source Voltage, 5 steps from 0.01 v/div to 0.2 v/div.

Type 575 Transistor-Curve Tracer $975

HIGH-CURRENT ADAPTER

For measuring high-powered semiconductor devices which exceed the current capabilities of a Type 575, ask your Tektronix Field Engineer about the Type 175 High-Current Adapter. Not intended for separate use, the Type 175 depends upon the circuitry and crt of a Type 575 to provide *200-ampere collector displays, three ranges of collector supply, and 12-ampere base supply*—for calibrated displays with Collector Current on the Vertical Axis and either Collector Voltage or Base Voltage on the Horizontal Axis.

Type 175 Transistor-Curve Tracer High-Current Adapter $1425



HIGH-VOLTAGE TYPE 575

Supplied on order from your Tektronix Field Engineer is a special model of the Type 575 Transistor-Curve Tracer. Although similar to the Type 575, the special model provides much higher diode breakdown test voltage (*variable from zero to 1500 volts* at a maximum current of 1 milliampere) and also much higher Collector Supply (*up to 400 volts*, at 0.5 ampere).

For complete specifications of this special model—call your Tektronix Field Engineer.

Type 575 Mod 122C $1175

(prices f.o.b. factory)

. . . for more information about evaluating semiconductor devices with a Type 575 or other Tektronix test equipment, call your Tektronix Field Engineer. He will be glad to assist you.

Tektronix, Inc. *P. O. BOX 500 · BEAVERTON, OREGON / MItchell 4-0161 · TWX—BEAV 311 · Cable: TEKTRONIX*

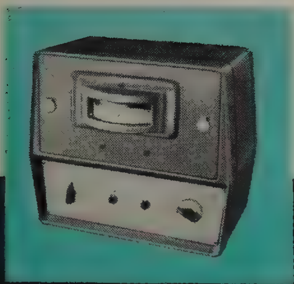
TEKTRONIX FIELD OFFICES: Albuquerque, N. Mex. • Atlanta, Ga. • Baltimore (Towson) Md. • Boston (Lexington) Mass. • Buffalo, N.Y. • Chicago (Park Ridge) Ill. • Cleveland, Ohio • Dallas, Texas • Dayton, Ohio Denver, Colo. • Detroit (Lathrup Village) Mich. • Endicott (Endwell) N.Y. • Greensboro, N.C. • Houston, Texas • Indianapolis, Ind. • Kansas City (Mission) Kan. • Los Angeles, Calif. Area (East Los Angeles Encino • West Los Angeles) • Minneapolis, Minn. • Montreal, Quebec, Canada • New York City Area (Albertson, L.I., N.Y. • Stamford, Conn. • Union, N.J.) • Orlando, Fla. • Philadelphia, Pa. • Phoenix (Scottsdale) Ariz. Portland, Oreg. • Poughkeepsie, N.Y. • San Diego, Calif. • San Francisco, Calif. Area (Lafayette, Palo Alto) • Seattle, Wash. • Syracuse, N.Y. • Toronto (Willowdale) Ont., Canada • Washington, D.C. (Annandale, Va.).

ENGINEERING REPRESENTATIVES: Kentron Hawaii Ltd., Honolulu, Hawaii. Tektronix is represented in twenty-five overseas countries by qualified engineering organizations.

European and African countries, the countries of Lebanon and Turkey, please contact TEKTRONIX INTERNATIONAL A.G., Terrassenweg 1A, Zug, Switzerland, for the name of your local engineering representative.

Other Overseas areas, please write or cable directly to Tektronix, Inc., International Marketing Department, P. O. Box 500, Beaverton, Oregon, U.S.A. Cable: TEKTRONIX.

Circle No. 17 on Reader Service Card



JMC type C8 control unit pulses power input to furnace, indicates temperature and provides fail-safe over-temperature protection.

UNIFORM TEMPERATURES TO 2730° F

Rugged as they are attractive, the new JMC Model K High Temperature Furnaces are real performers too:

- Platinum wound for lowest operating costs
- Windings totally embedded in high purity alumina
- Hot zone of uniform temperature
- Elements easily replaced, even on hot furnace
- Minimum heat loss . . . may be operated on unprotected work bench
- Two integral thermocouples, embedded in refractory
- Variety of general purpose models, with combustion chambers up to 21½ in. long by 2½ in. dia.
- Ash Fusion and Controlled Atmosphere model with sighting window and bursting disc
- Thermocouple Calibration model for temperature up to 3225° F

Model K furnaces are the result of Johnson Matthey's unsurpassed experience in platinum-wound furnace design and manufacture.

For complete information, send for Technical Data Sheets.

Johnson Matthey

JOHNSON, MATTHEY & COMPANY, INC. • 608 Fifth Avenue, New York 20, New York • Telephone Circle 5-6790

Circle No. 18 on Reader Service Card

Industry News

CONFERENCE CALENDAR

The Following November 1961 Meetings Are Schedule

Nov. 1-3 International Conference on High Magnet Fields, MIT, Cambridge, Mass.

Nov. 6-8 Special Technical Conference on Non-Lin ear Magnetics, Statler-Hilton, L. A. Spon sored by PGEC-PGIE, AIEE. For Informa tion: Dr. Ted Bernstein, Space Technolog Labs, POB 95001, L. A., 45, Cal.

Nov. 13-16 7th Annual Conference on Magnetism Magnetic Materials, Hotel Westward H Phoenix, Ariz. Sponsored by IRE, AIEE, A Phys., ONR, AIME. For Information: F. E Luborsky, G.E. Res. Lab., POB 1088, Sche nectady, N. Y.

Nov. 14-16 NEREM (Northeast Research & Engn Meeting), Somerset Hotel & Commonwealt Armory, Boston, Mass. Sponsored by Regio 1. For Information: F. K. Willenbrock, Pierc Hall, Harvard Univ., Cambridge 38, Mass.

Nov. 14 Symposium on Electronic Systems Reliabil ity, Linda Hall Library Aud., 5109 Cherry Kansas City, Mo. Sponsored by Kansas Cit Section. For Information: Arthur Goldsmit Wilcox Electric, Kansas City, Mo.

Nov. 20-21 Electron Devices Meeting, Shoreham Hote Wash., D. C. Sponsored by IRE/PGED.

Nov. 24-25 American Physical Society Meeting, Chicag Sponsored by AIS.

Nov. 28-30 Winter Conference, EIA. Statler Hilton, L. A

Nov. 27- Dec. 1 28th Exposition of Chemical Industries, Ne York Coliseum, N. Y. C.

A study of Research and Development in the Chicago Area Electronics Industry is in its final stages at Northwestern University. Started early in 1961, it is schedule for completion in time for the results to be presented a the National Electronics Conference in October. It wa initiated by the Professional Group on Engineering Management (PGEM) of the Institute of Radio Engineers an has been sponsored by the National Electronics Conference and supported by grants from more than 25 Chicag electronic companies. The project is under the directio of Albert H. Rubenstein, Professor of Industrial Engineering at Northwestern University. The study is aime at a better understanding of the relationships between th following factors in the Chicago-Area Electronics Industry: management attitudes toward research, attitudes o the financial community, research climate in the community, resources allocated to and constraints impose upon company research and development, R and D capabilities in the Chicago area, R and D achievements o Chicago companies, and economic results (primarily rate of growth).

Essential terms for the purchase by Raytheon of the al estate, physical facilities, and certain inventories from BS Electronics have been agreed upon, it was jointly nounced recently by Richard E. Krafve, president of aytheon Company and Clarence H. Hopper, president of BS Electronics. The agreement was reached following BS Electronics' decision to discontinue its semiconductor erations.

C. I. Hayes, Inc., during the Metals Show scheduled for ctober 23 through 27 at Cobo Hall in Detroit, Michigan, ill demonstrate, along with other equipment, the pHayes-aster (TM), a power control device incorporating the test in transistorized circuitry. pHayes-master accom-ishes in a very compact unit the same functions which ould otherwise require bulky saturable core reactors, agnetic amplifiers, and other space-consuming units, ac-rding to the company. It features microsecond response us a high power factor, resulting in high-sensitivity, gh-precision control of furnace temperatures and simi-r operations.

RESEARCH and DEVELOPMENT

An electroluminescent crossed grid display device, a " x 16" panel, was described recently by engineers of ylvania Electric Products Inc. The new panel is com-osed of four individual crossed grids, with a resolution of lines per inch, and demonstrates the feasibility of man-facturing even larger units employing a modular building ock construction. To overcome the difficulty of intercon-ecting panels to form an electrical path, each line of the ossed grid is continued around and to the back of each nel. The panels are then affixed to Sylvania-designed nnector boards which permit ease of servicing and ad-stment. Joining small electroluminescent panels into a ntinuous large display, demands extreme accuracy of nel size, and according to the company, they have hieved this accuracy within .002" of the required di-ensions.

A solid-state microwave transmitter for space commu-cations was announced recently by General Telephone & ectronics Corporation. The transmitter, less than the size a cigarette carton, occupies about one-seventh the space, s 11 times the life expectancy, and ten times the fre-ency stability of conventional transmitters. The trans-itter could be combined with a solid-state ultra-reliable dio receiver developed earlier by GT&E to form a com-ete space communications system. The system would used for space probes, or would be a major element a satellite communications system used to transmit lephone conversations, business data, or television pro-ams on a world-wide basis, utilizing satellites 22,300 iles above the earth as relay stations.

Developed for the Air Force, the compact transmitter it, which occupies about 55 cubic inches, is the first lid-state transmitter designed to operate with two watts output power within the S-band (1700 to 2300 mc). ese are considered to be the minimum power and fre-ency requirements for transmission of information be-een two points on the earth's surface via an active lay satellite in a "stationary" equatorial orbit. The de-lopment raises the known upper limit of power output om solid-state transmitters at these frequencies to two atts from the previous range of .03 watt and .05 watt.

(Continued on page 55)

Off the Presses ...

SEMICONDUCTOR DIODE SOURCE BOOK

- CONTAINS COMPLETE CHARACTERISTICS OF MORE THAN 2,800 TYPES.
- TWO SETS OF CHARTS PROVIDE:
  1) NUMERICAL TABULATION
  2) LISTINGS IN ORDER OF MOST IMPORTANT DESIGN PARAMETERS.*
- AN ADDITIONAL CHART LISTING AVAILABILITY OF DEVIC
  FROM VARIOUS MANUFACTURERS.
- CHARTS ARE NOTEWORTHY FOR THEIR EASE OF USE AND COMPLETENESS OF PARAMETERS.
- PACKAGING INFORMATION INCLUDED.
- CHARTS PREPARED BY THE NATIONAL BUREAU OF STANDARDS.

*Separate charts are provided for each diode type. These charts are arranged in an ascending order of the numerical values of the most important parameter of the device. This permits a rapid selection of a specific type to meet the needs of the design engineer.

ORDER YOUR COPY NOW!

Price only **$2.50** postage paid in the U.S.A. and possessions.

SEMICONDUCTOR PRODUCTS SCP10
300 W. 43rd St., New York 36, N.Y.
SIRS: My check (money order) for $____ is enclosed.
Please send Semiconductor Diode Source Book to:

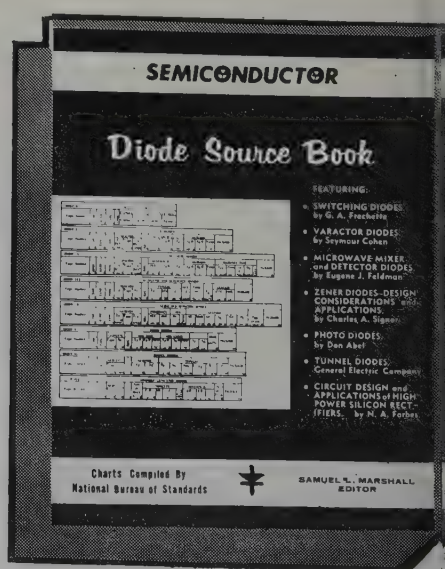
NAME ____________________

STREET ADDRESS ____________________

CITY ________ ZONE ________ STATE ________

N.Y. City residents add 3 % Sales Tax.

$ 2.50



WHY SEARCH FOR:

m. r. K.*

in METALS and ALLOYS

*MATERIAL RELIABILITY CONSTANT

SPECIFY...

E M A

The single most critical factor in semiconductor design and production is the reliability Constant of the materials used in the manufacturing process.

Only dependable material consistency and quality can guarantee: good product, high yield, and efficient reproducibility.

The primary concern of metallurgists at E.M.A. is to reduce your manufacturing variables by producing the finest in semiconductor parts and materials. This is why Electronic Metals and Alloys, Inc. has brought a new order of reliability to the industry with its m. r. K* program.

Specify E.M.A. for quality, for price, for performance.

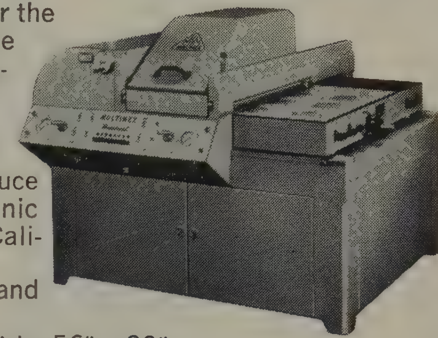
For technical information on E.M.A.'s products, analytical services, and materials application engineering, write:

60 ARSENAL STREET • WATERTOWN 72, MASSACHUSETTS

Electronic Metals and Alloys inc.

Circle No. 23 on Reader Service Card

MICROMINIATURIZE TO PINPOINT PRECISION
BY AUTOMATIC STEP & REPEAT ON THE ROYAL ZENITH MISOMEX

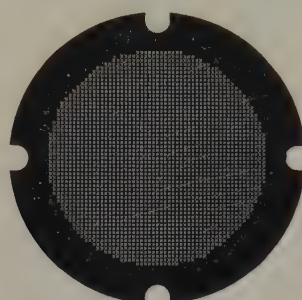


/iniature circuitry patterns are completed in minutes—accurate to .001 over the ntire exposure area—on the automated MISOMEX. Starting with one simple iece of artwork the MISOMEX automatically positions and exposes in regular, stepped or staggered patterns, with simple push-button control. Automatic microminiaturization on the MISOMEX cuts time and labor costs o a minimum, eliminates human errors.

/ISOMEX is the only automatic step-and-repeat machine now in use to produce nicrominiaturization assignments. For a wide range of tasks in electronic ircuitry, companies like IBM, Itek, Buckbee Mears, Etching Company of Caliornia and other leading electronics firms use MISOMEX.

/ISOMEX with fully automatic push-button controls is available in 25″ x 26″ and 9″ x 43″ sizes with negative chase sizes up to 9″ x12″.

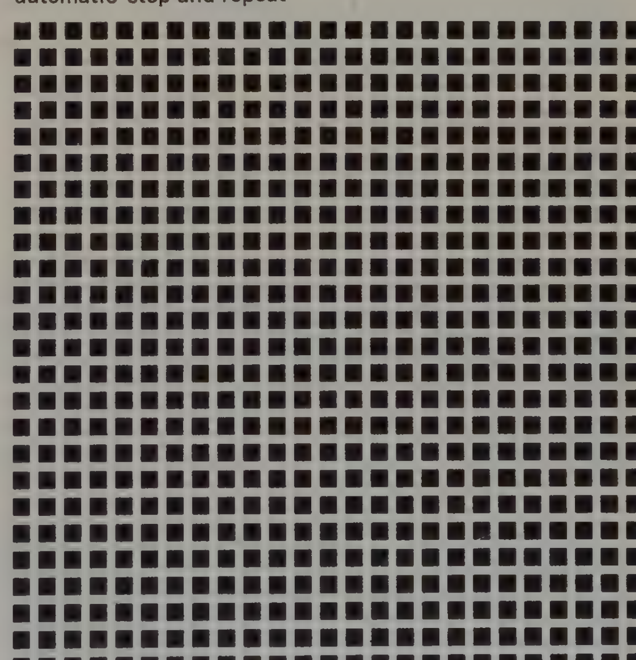
Also available: The Punch Card Control MISOMEX in sizes from 40″ x 56″ to 56″ x 80″ vith chase up to 24″ x 24″. Any model with incandescent or water-cooled, high-intensity Xenon light source.



THIS
completed
microminiaturization
circuit grid

FROM
one piece of
artwork like this

THROUGH
camera reduction and
automatic step-and-repeat

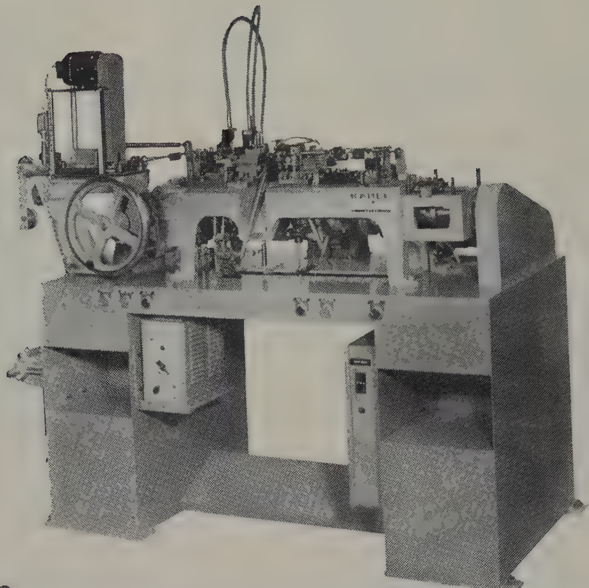


FOR COMPLETE INFORMATION, WRITE:

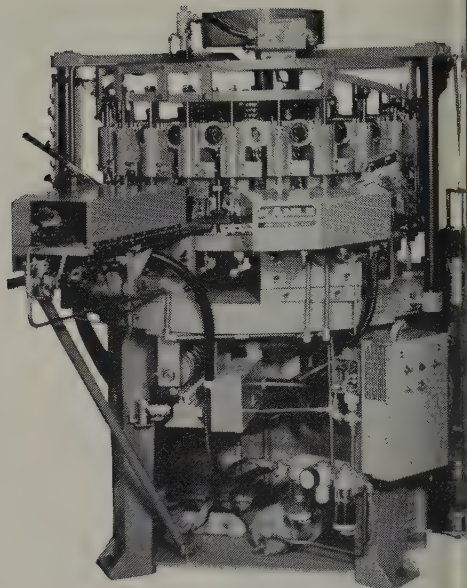
ROYAL ZENITH CORPORATION

180 VARICK STREET, NEW YORK 14, NEW YORK
619 W. WASHINGTON BLVD., CHICAGO 6, ILL.
1350 S. BROADWAY, LOS ANGELES 15, CALIF.

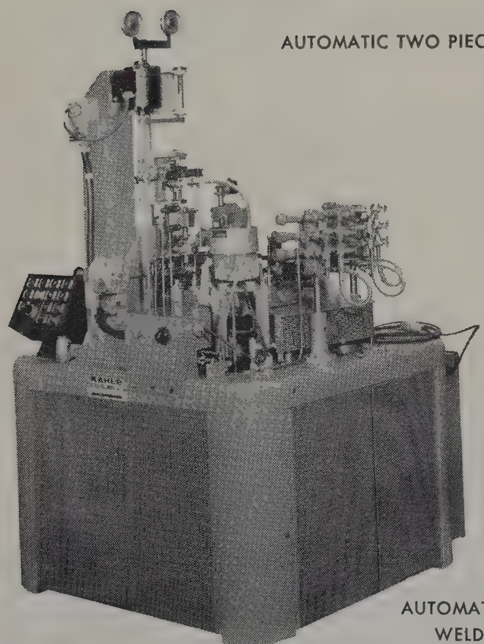
Circle No. 24 on Reader Service Card



AUTOMATIC TWO PIECE LEAD WELDER 3648



AUTOMATIC FINAL SEAL 3383



AUTOMATIC LEAD BEADING — WHISKER
WELDER AND FORMER (RIBBON) 3665

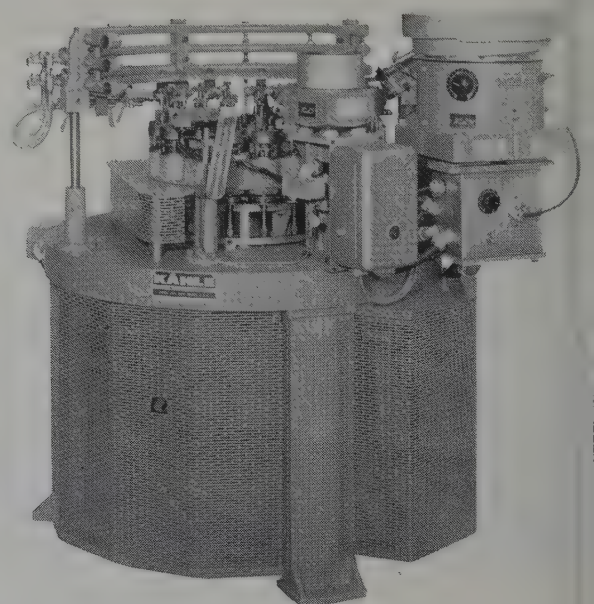
....latest in the series
of automatic machines
designed and built by KAHLE
for critical operations
in the volume production
of newly developed components

KAHLE
ENGINEERING COMPANY

3322 HUDSON AVENUE
UNION CITY, NEW JERSEY

DESIGNERS AND BUILDERS
OF PRODUCTION MACHINERY

AUTOMATIC EQUIPMENT & METHODS
FOR MANUFACTURING TRANSISTORS
CRYSTAL DIODES, ELECTRON TUBES



AUTOMATIC BODY CASE (MOLY OR
DUMET SLUG LEAD OR GLASS BEAD) 3624

Circle No. 25 on Reader Service Card

Editorial . . .

Energy Converters

To permit an efficient utilization of the process, energy in the form of radiation, heat, chemical action, nuclear action, mechanical action, etc., generally must be converted into electrical form. Various novel conversion processes have been developed using photoelectric, thermoelectric, thermionic, and magnetohydrodynamic devices. In addition, systems based on the Curie inversion temperature and on antistokes fluorescence have been proposed.

The methods based on photoelectric and on thermoelectric devices are of particular interest to the semiconductor art. Photoelectric devices utilize the photovoltaic effect obtained at a p-n junction diode when radiation is incident on a region including the depletion layer. The useful radiation is that in which the wavelength is less than ch/qV_g, where V_g is the semiconductor gap and q, h and c are respectively electron charge, Planck's constant and velocity of light.

For example for germanium $\lambda_{max} \cong 1.7\ \mu$, and for silicon $\lambda_{max} \cong 1.12\ \mu$. Since the radiation spectrum of a black body is a function of temperature, only a fraction of the incident radiation energy can be converted, depending on the temperature of the black body and on the energy gap. In addition, even for photons of wavelength less than λ_{max}, the quantum efficiency is generally less than unity.

Assuming that the quantum efficiency is unity, it is found that the maximum current density obtainable with a silicon diode under bright sunlight at sea level is 440 A/sq. m, and that obtainable with a germanium diode is 680 A/sq. m. Using semiconductors with even lower gap V_g, a current density of 800 A/sq. m could be approached. However, the available power is dependent upon the current and the voltage. Since the latter increases with V_g, an optimum value of V_g may be computed.

In idealized conditions a value of 1.3 eV is found. For this reason, silicon is considered the most suitable semiconductor for this application. Silicon solar cells have been built with a conversion efficiency of the order of 10% (theoretical maximum 20%), and a weight per kilowatt ratio of about 1000 lb/kw. Current efforts are directed at increasing the efficiency by growing more perfect crystals and by using such semiconductor compounds as GaAs and CdS. The best predicted results are of the order of 120 lb/kw.

Thermoelectric devices utilize the thermoelectric emf produced in a circuit of two different metals or semiconductors, the contacts of which are at different temperatures. This effect is caused by the variation of the Fermi levels with temperature, and by the drift of free carriers from high to low temperature regions. The variation of Fermi levels with temperature is larger in semiconductors than in metals, and even the drift motion of electrons takes place more freely in semiconductors. As a result the latter are found useful for the design of energy converters. For example lead telluride compounds possess practical energy conversion efficiencies of the order of 10% (theoretical value 30-40%) and a weight per kilowatt ratio of the order of 65 lb/kw. Lower specific weights are expected with continued improvements.

In closing, it must be pointed out that other types of energy converters appear even more promising than those described above. For example, thermionic generators, utilizing a diode in a plasma atmosphere, have efficiencies of the order of 4-10% (theoretical value 40%) and a weight per kilowatt ratio of only 1 lb/kw.

The Use of R-F Heating in Growing Crystals by the Czochralski Technique

W. A. EMERSON*

This article discusses the various aspects of induction heating as it pertains to its use in the Czochralski technique for growing semiconductor crystals. The general design parameters of the induction coil are given, as well as a discussion on temperature control. Also mentioned is a brief explanation of the theory of induction heating.

IN APPLYING RADIO-FREQUENCY induction heating in the semiconductor industry a number of problems are encountered with enough similarity to warant their classification as general problem-types. In he classification, individual problems can be grouped ccording to the extent to which they involve these ve aspects of function:

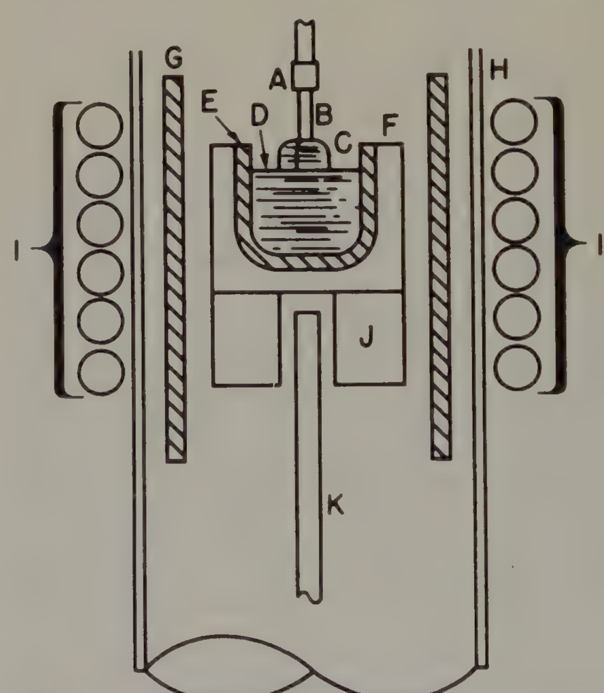
1. Heat distribution
2. Loading the *r-f* generator
3. Coil design
4. Radiation losses
5. Temperature control

Of these, problems of heat distribution and loading re closely related to coil design. Problems of radiaon losses, although not electrical are quite imporant since they govern the size of the power source equired more than anything else. Listed last but robably most important of the group is temperature ontrol.

he Furnace

The basic vertical crystal-pulling furnace, shown hematically in *Fig. 1,* is used to obtain a single rystal of silicon or germanium from a polycrystalline aw material. A quartz crucible, **E**, is shown for use ith silicon. It is not normally used when germanium being processed. Also shown in this figure is the apphire rod, **K**, which is used for temperature senng. A thermocouple mounted in the graphite rucible could just as easily be used for temperature ensing or an optical sensing device might be used.

Induction heating is the heating of a conducting aterial by means of the power loss in this conductg material showing up as the I^2R loss in the mateal, where the current is caused to flow by means of an induced voltage in the material. To elaborate on this, it may be seen, in referring to *Fig. 1,* that the inductor coil **I** has an alternating current flowing through it. This sets up an alternating magnetic field which will induce a potential into any conducting material which is in the field. The closest conducting material to the coil is the graphite crucible holder **F**. The only other conducting material in the magnetic



A — Chuck for holding seed crystal.
B — Seed crystal.
C — Partially grown single crystal.
D — Molten silicon (or germanium).
E — Quartz crucible (for silicon only).
F — Graphite crucible holder.
G — Heat shield.
H — Furnace enclosure.
I — Inductor coil.
J — Crucible support.
K — Sapphire rod.

Fig. 1—Typical Czochralski furnace.

*Industrial Electronics Department
Westinghouse Electric Corporation
Los Angeles, California

field is the molten silicon but this usually does not heat inductively—as will be described later. The potential appearing across the impedance of the crucible holder **F** causes a current to flow around the periphery of the holder. This current flowing through the resistance of the crucible holder periphery causes a power loss on the surface of the crucible holder which shows up as a temperature rise. This temperature rise on the surface is then conducted into the quartz crucible and finally to the silicon itself. Because of the temperature differential between the crucible holder and the furnace enclosure **H**, radiation of heat becomes a very serious problem. The purpose of the heat shield **G** is to reduce the radiated energy at high temperatures. For the temperature of the crucible to rise it is necessary to put more power into the crucible than is radiated from the crucible. This may sound rather elementary—however, it is very often neglected when considering a heating problem. It is especially important where a relatively low mass is heated to relatively high temperatures, as is usually the case in semi-conductor work. The actual thermal power required to melt several hundred grams of silicon in 15 minutes is approximately 1 *kw,* whereas the radiation from the surface of the crucible holder is usually a number of kilowatts.

Because a high frequency is usually used for heating the graphite crucible holder in this operation, there is a definite tendency to obtain a "skin effect" on the holder. This depth of current penetration is easy to calculate using the formula $\delta = 1.98 \sqrt{\frac{\rho}{f}}$ where δ is the depth of current penetration in inches, ρ is the resistivity in micro-ohm centimeters and f is the frequency in cycles per second. From this it becomes apparent that the depth of penetration changes during the heating because the resistivity of the graphite changes. With a resistivity of 920 micro ohm-cm for graphite at 1400 degrees C and standard frequency of 450,000 *cps* the depth of penertation is .089 inch. From this it is obvious that at this frequency and with relatively thick crucible holders practically none of the magnetic field and consequently none of the heating occurs in the silicon itself. It may also be deduced that there will be no stirring or agitation of the melt due to the magnetic field.

The R. F. Coil and Temperature Distribution

In induction heating the inductor coil (which, incidentally, is almost always copper tubing with water flowing through it) is usually a loosely wound, loosely coupled coil. This may be seen in *Fig. 1.* However, to understand why a coil heats the way it does, the coil and susceptor are redrawn in *Fig. 2.* Susceptor is merely the name of any material in the magnetic field which will heat, i.e., it is susceptible to the *r-f* energy. In this case, the susceptor is the crucible holder and support which are both made graphite.

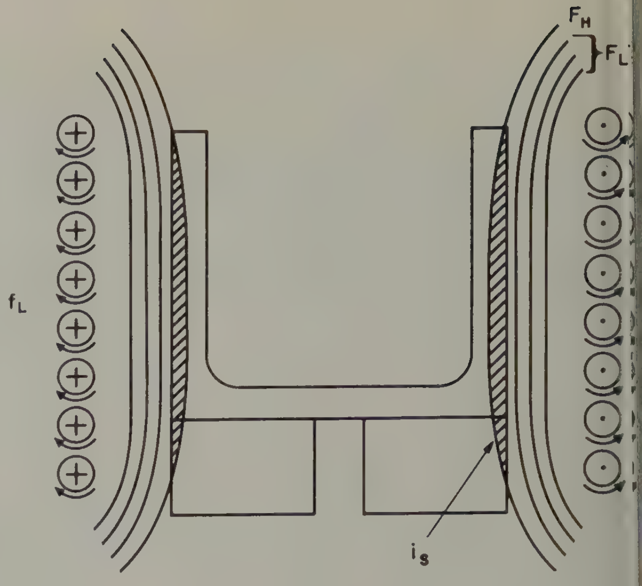


Fig. 2—Flux paths around a susceptor.

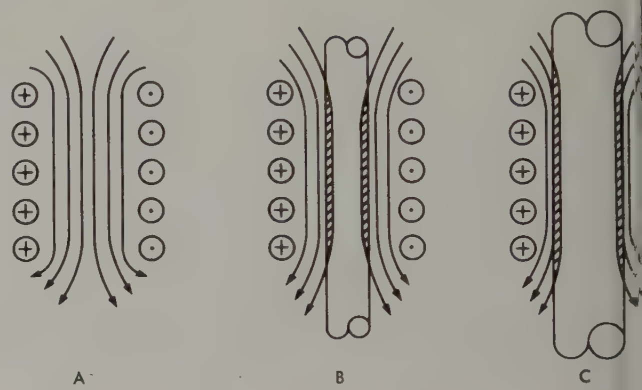


Fig. 3—Flux paths with various couplings to the susceptor.

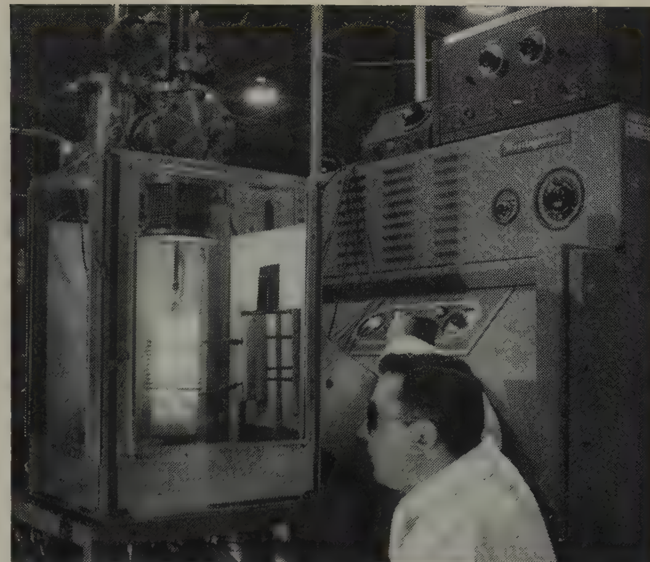
As in any coil with current flowing through t wire, a magnetic field is set up around each turn the wire. This field or flux is represented by t arrows encircling the turns with f_L representi leakage flux, F total flux F_L total leakage flux a F_H the flux actually passing through the suscept In this relation $F = F_L + F_H$. The F_H, in the case an alternating current flowing through the coil, duces a current in the susceptor. This current, flows in the opposite direction to i_c and thus sets a field of its own which opposes the flux field set by the coil. This field is great enough in the case the high currents used in induction heating to grea distort the field set up by the coil and to cause a ve high percentage of the total flux to appear as to leakage flux, F_L. For this reason very high *kva* ta circuits are required so that reasonable quantities power may be developed in these low power fac circuits. Before this fact is elaborated on it may

vell to look at *Fig. 3*, which shows three coils and heir flux paths. *Fig. 3a* is the coil with no susceptor, *'ig. 3b* is coil and susceptor with loose coupling, and *'ig. 3c* is with tight coupling.

As may be seen in *Fig. 3a* the flux inside the coil s relatively uniform except at the ends of the coil vhere the flux lines no longer run parallel to the ength of the coil but curve around the coil. In *Fig. 3b* a conducting nonmagnetic material is placed inside he coil but with a rather large radial clearance beween the coil and work. In this case most of the flux s forced between the coil and the material with elatively little flux entering the material. What flux loes enter the material, however, goes to a depth of δ vhich was defined earlier as the depth of current penetration. Now in the case of *Fig. 3c* we have the condition known as tight (or close) coupling where he radial clearance between coil and material is small. In this case, a considerably greater amount of the flux is forced into the material but still only o the same depth δ. Thus, it becomes apparent that for a given frequency and voltage across the coil the amount of power induced into the material will be greater for *Fig. 3c* than for *Fig. 3b*. Another important phenomenon which occurs in a close-coupled coil is that a greater amount of heating will appear mmediately under the turns of the coil. This is due o two factors. One is that the frequency used gives such a low figure for δ that the spacing between turns of the coil is greater than this value. The current flow through the work cannot be uniform if it s not induced uniformly to begin with. The second factor is that it is not induced uniformly because the eakage flux is greater between the turns of the coil than immediately under the turns of the coil. This may better be shown in *Fig. 4*.

The excessive heating underneath the turns of the coil is greatly minimized if not completely eliminated when the coil is loosely coupled. This occurs because the field between the coil and the susceptor becomes fairly uniform as the radial spacing increases.

This phenomenon is thus very important in semiconductor work where a crucible must be heated to very uniform and precise temperatures. In many instances, however, a definite temperature taper is desired. From the above discussion it becomes apparent that there are two ways to accomplish this. One is to increase the radial clearance between the coil and susceptor, allowing more flux leakage where the clearance is greater and thus inducing less power into that portion of the susceptor. This is usually not done because it necessitates the use of a tapered coil which is not the easiest type to build. The other method is to merely increase the longitudinal spacing of the coil turns at one end. This reduces the heating at that end simply from the fact that less flux is generated per given length. This type of coil modification is quite simple and is the method usually used.



Crystal pulling furnace at the Westinghouse Semiconductor Dept., Youngwood, Pa. The furnace uses a 10 WK, 450 *kc* power supply. Programmed control continuously monitors the crystal growing process.

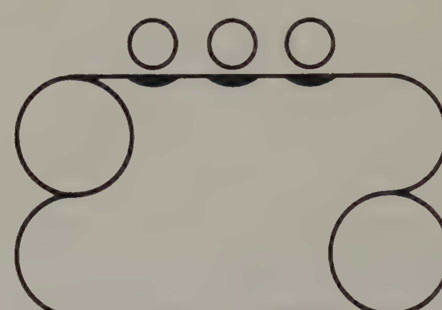


Fig. 4—Effect of close coupling on temperature distribution.

It was mentioned earlier that the flux lines start expanding as they approach the end of the coil. This is due to the fact that they are curving around the end of the coil and returning around and outside of the coil. The effect will be to reduce the amount of power induced in the work at this point since the density of flux per cubic inch of work is less. This may be compensated for by three different methods. Two of them were outlined just previously to get a tapered heat. That is, the coil could be pulled in closer to the work or the number of turns per inch could be increased. Either of these methods can result in a coil which will give reasonably good temperature distribution. However, they usually require a fair amount of "hand tailoring" to get what is desired. A simpler method and the one usually used is to increase the length of the coil beyond the work. Thus, the field is still relatively uniform where the work stops. A good rule of thumb for this length is to make the extended length equal to the radius of the coil. Of course, combinations of these various methods may be used where it is felt desirable. For

example, because of the furnace construction it may not be possible to get more than half the radius belond the end of the crucible. In this case it would be highly desirable to increase the number of turns per inch as the end of the coil is approached.

Power Factor

The term *kva* has been used several times and for one to understand the application of induction heating this should be elaborated upon. *kva* is actually the product of kilovolts times amperes. When referring to tank *kva* in an *r-f* generator this is the kilovolts available in the tank circuit times the circulating amperes in that same circuit. The work coil (or inductor) *kva* would of course be the voltage across the work coil times the current through the coil. Power is equal to *kva* times power factor. The power factor of the coil-crucible assembly is dependent upon the physical constants of the coil and crucible. These are the resistivity of the crucible, its dimensions, the radial clearance between coil and crucible, number of turns in the coil, length of the coil, and to a limited extent, the location of crucible in coil. Because the requirements of the crystal pulling furnace are established in advance, very few of the physical constants can be changed. The material of which the crucible is made is fixed. It must be large enough to hold the material to be melted, radial clearance is kept to a minimum, and since the crucible must be on the inside of the furnace structure and the coil on the outside, this is usually in the order of one inch; the number of turns in the coil is usually a maximum with a reasonable spacing of approximately ⅛ inch between turns and a reasonable size of copper tubing (¼ inch o.d. to ½ inch o.d., with ¼ and ⅜ inch being the most popular). The length of the coil is that which is necessary to get a proper heat pattern on the crucible and the location of the crucible is where the best heat pattern may be obtained. A typical silicon furnace powered with a 25 *kw* *r-f* generator may have a coil with 2000 volts across it and 200 amperes through it. This would give 400 *kva* in the coil. Now, if this is loading 15 *kw* from the generator then the power factor would be $\frac{15}{400} \times 100 = 3.7$ percent. Typical power factors for crystal pulling furnaces are from about 1 percent to 8 or 9 percent. Because of these extremely low power factors the *r-f* generators must be designed with high tank *kva* in order to be able to draw the full power from the generator. A typical tank value for a 25 *kw* generator is 2100 *kva*. This would allow a coil with a power factor of only 1.2 percent to draw full power from the generator.

Voltage

Another important design consideration is to keep the voltage across the coil as low as possible. High voltage across the coil causes undesirable results such as excessive ionization of the inert gas in the furnace, arcing from sharp corners of the crucibl and worst of all, the possibility of an arc betwee turns of the coil or from the coil to the ionized g in the furnace. These last two mentioned arcs w usually throw an overload on the generator an cause the protective devices in the generator to r move plate voltage from the oscillator. When th occurs there is a good chance of the melt freezin and thus causing the loss of hundreds of dolla worth of material and set-up time. There is the po sibility that the copper tubing will be punctured b the arc and then water will spray from the coil on the hot furnace. There is also a good chance that th furnace chamber will be punctured by the arc an thus necessitate a costly repair. As was stated earlie for a given coil and crucible configuration a certa *kva* is required. This *kva* may come from either high voltage and low current or vice versa. Th latter, of course, is the more desirable. In othe words, the *r-f* generator should be run with a rathe high *r-f* current (close to maximum), and the co design should be such that only enough voltage developed across the coil to accomplish the desire heating effect. It is entirely possible that the co when placed across the generator, does not dra close to full current and the voltage across the co is not adequate to accomplish the desired heatin This may be compensated for rather easily by ad justing the tap on the tank coil. *Fig.* 5 shows th schematic of a typical oscillator for induction heatin

Frequency

It may be noted that the work coil WC, the tan coil TC, and the grid drive coil GD are all in serie and together form the inductance in the tank circui The tank capacitor CAP is across this inductance an they resonate at the operating frequency of th generator. A certain *r-f* voltage, E_{rf} appears acros the tank and is divided among the three coils i series. It may be seen that if some of the tank co turns are shorted that more of the E_{rf} will appea across GD and WC. This of course will also lowe the inductance of the tank circuit and thus raise th frequency of the generator. A higher *r-f* current wi then flow due to the reduced reactance of the tan

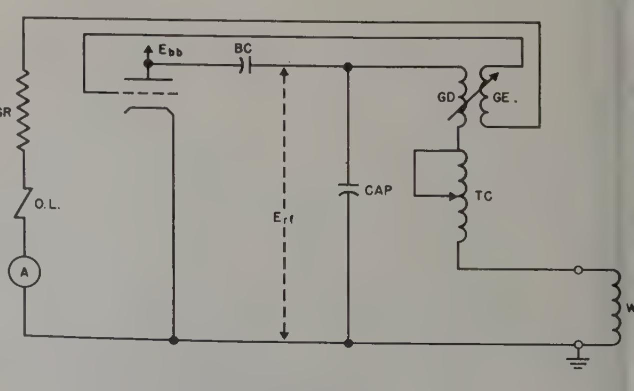


Fig. 5—Typical oscillator schematic.

capacitor. These effects put more *kva* into the work coil, more power into the work, and consequently more power is drawn from the generator. As noted, when the work coil is changed or when the tank coil taps are changed, a change in frequency occurs. The frequency of operation is usually not too critical. The major restrictions on frequency should be a maximum of 490 *kc* due to F.C.C. restrictions and a minimum of such value that adequate grid excitation current is obtained. This is usually down around 200 to 250 *kc*. Some generators are designed to go down to as low as 200 *kc* by changing taps on the grid excitation coil and thus having more turns. Since depth of current penetration varies inversely as the square root of the frequency, it can be seen that by going from 450 *kc* down to 225 *kc* the depth of penetration will increase by a factor of 1.414. δ will increase from .09 at 450 *kc* to .13 inches at 225 *kc*. At first glance this may seem like a significant change, but from a thermal standpoint, it has little meaning. This may be explained by assuming a crucible of a typical diameter, such as 2½ inches. Heat at the center of the crucible must get there by conduction from the surface minus the value of delta. Thus in one case conduction is over a distance of 1.16 inches and in the other case, conduction is over a distance of 1.12 inches. This is an improvement of only about 3.5 percent.

Heat Radiation

Radiation losses are a major problem when high temperature work is carried on. Since these losses go up directly with the fourth power of the absolute temperature, it becomes apparent that they are very significant at 1400 degrees C. Besides requiring a large r-f generator power source to supply these losses, the radiation is an annoyance to the operator of the furnace and causes overheating of various components of the furnace.

It is an absolute necessity to place a radiation shield around the graphite crucible to cut down losses to the point where a reasonable sized generator may be used. The shield is usually a tubular section of aluminum oxide approximately ⅛ inch in wall thickness and of such dimensions that there is a small amount of radial clearance between the crucible and the shield. Sometimes opaque quartz is used for a radiation shield. These nonconducting materials have several advantages over metallic shields. They do not have to be split and are thus quite rigid, they are relatively inexpensive and easy to replace, and they can operate at high temperatures with no damage. Occasionally, a tantalum sheet bent around the furnace is used as a shield. This has the disadvantage of having to be split to avoid induction heating and it must be kept relatively cool if it is to maintain its shiny surface and thus its maximum efficiency. Gold is also sometimes used. This has the same disadvantages as tantalum, however, it can be deposited directly on the quartz furnace structure and thus maximum rigidity is maintained.

To cut down the radiant heat, a double wall furnace structure is sometimes used and water is circulated between the double walls. This cuts down the heat around the furnace, making it more comfortable for the operator, as well as helping to keep the various components cool. If a metallic shield is used, the water wall can be used to cool the shield. This construction has two distinct disadvantages. One is that there is always the danger that the internal tube can break and flood the hot crucible with water. This of course can be extremely dangerous. The other disadvantage is that a double wall obviously requires more radial clearance between the coil and the crucible. This will give the system a lower power factor and more *kva* will be required at the coil to attain the necessary heat.

For some unapparent reason, when a wall of water is used between the coil and crucible, ionization of the inert gases inside the furnace is not as prevalent.

An adaptation of the water wall is to surround the inductor coil itself with water. By doing this a major portion of the radiant heat is eliminated but without the disadvantage of increasing the radial clearance of the coil. There is some minor arcing and "spitting" due to conduction of electricity through the water, but this is of a minor nature if distilled or deionized water is used.

Controllers

To pull a satisfactory silicon crystal, a temperature of approximately 1420 degrees C is required and a control of $\pm$ .2 degrees C is desirable.

Several controllers have been designed specifically with this extreme precision in mind and some of the *r-f* generators available are designed with power controls to be compatible with these controllers to accomplish the end result.

Basically three types of controllers are available. These are:

1. Mechanical position adjusting
2. On-Off pulse control
3. Continuous electronic control

The first type is merely a controller which feeds a signal into a servopositioning motor which drives a mechanically-operated power control up or down, depending upon whether more or less heat is required. This type of control, although very desirable in many industrial applications, is of little use in present-day semiconductor work.

The second type of control is an *on-off* pulse control where the number of pulses per second remains constant but the duration of *on*-time for each pulse is changed according to the power requirements. This type of control was used extensively in early semiconductor work.

The third type of control is a continuous adjustment of power output with no mechanical coupling or linkages required. This control is used practically

exclusively in present-day semiconductor work. See *Fig. 6*. With this method, a continuous signal of from 0-5 milliamperes is received from the controller. This signal is then fed into a magnetic amplifier which amplifies the signal to a level necessary to control the power output of the *r-f* generator by means of saturable reactors. The control signal is a function of the temperature sensed by the radiation detection device. The entire system has a certain amount of thermal inertia which tends to damp short-term variations in the power due to line voltage fluctuations. Inertia will also slow down the recovery time when a fluctuation in output from the generator occurs. This of course is due to the fact that the control system cannot correct for a generator output change until this change shows up as a temperature change on the crucible. The short-time generator output change can be sensed by means of a pickup coil in close proximity to the r-f transmission line. The output from the pickup is rectified and fed into the temperature controller. Thus, any change in output from the generator is instantly sensed and is then corrected for by means of the same control sequence as occurs when a temperature change occurs. This extra feedback loop is highly desirable —since slight fluctuations in power line voltage are almost always occurring. Even if the line voltage regulation is quite poor this system will usually be able to compensate and maintain extremely close temperature control.

Temperature sensing may be accomplished by means of either a thermocouple or a radiation sensing device. The usual thermocouple combination used at these temperatures is platinum-platinum rhodium. The thermocouple, when used, is usually inserted into a hole drilled longitudinally and close to the surface of the graphite crucible. The thermocouple is inexpensive, rugged, and easy to replace but it has several decided disadvantages. It makes rotation of the crucible impossible; it senses the temperature only at the junction, and sometimes *r-f* energy is picked up by the thermocouple or its leads, causing trouble in the controller.

Radiation sensing devices do not have to be in close proximity to the crucible thus eliminating the *r-f* pickup problem. The device is usually focused on a fairly large area on the bottom of the crucible which allows it to integrate the radiant energy being emitted from the bottom. In this manner, if a slight change in the crucible occurs, such as a minor chip falling out, or a hot spot developing because of a fine crack, the over-all radiant energy reaching the sensing devices will show practically no change and the control continues to hold the correct temperature. By using a radiant sensing device, rotation of the crucible becomes possible. This is highly desirable because temperature around the periphery of the crucible can be held more uniform. The major disadvantage of a radiating sensing device is that energy must reach its sensitive thermopile through a lens

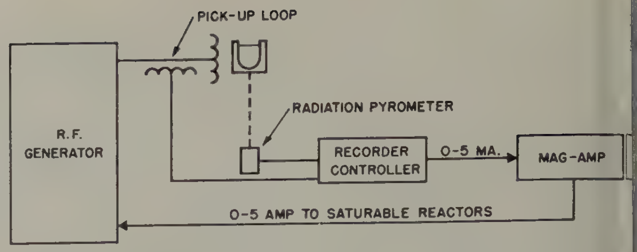


Fig. 6—Block diagram of a typical control system.

system and if this lens system is allowed to becom dirty then the energy reaching the thermopi changes and an erroneous temperature indication obtained. Fogging of the lens system can occur du ing a crystal pulling run while the furnace is seale This of course must be prevented as much as po sible.

The usual procedure here is to allow some (or al of the inert gas to flow over the lens, thus sweepi any solids away from the lens with the clean ga entering the system.

One type of radiation device available on th market uses a sapphire rod of about 3/16 inc diameter and any length up to about 18 inches part of the lens system. The end of the rod mounted in close proximity to the bottom of th crucible. In this type of system gas is not passe over the end of the rod and apparently fogging the end is not too serious a problem.

Resistance Versus Induction Heating

After this review of the principles of inductio heating in the semiconductor industry, it may b useful to consider some of the advantages and di advantages of induction heating, with particul reference to resistance heating.

Since the purity of the metals being processe must be high, every precaution must be exercise to prevent contamination. In this respect, the sim plicity of induction heating equipment contribute greatly to effectiveness. The susceptor and its sup port are made of high-purity graphite, and th crucible, radiation shield and furnace enclosure ar quartz, which is easy to clean. There is no need t bring high current leads to supply power for hea ing into the furnace enclosure; the heated portio (the susceptor) does not have spirals cut into it a does a resistance heater, and thus is infinitely easie to clean; and the simple construction of the suscepto which has no leads attached makes it easy and in expensive to replace if there is any question of co tamination in the graphite.

Inherent in the design of a resistance furnace greater thermal inertia which is evident as a mo sluggish temperature control cycle. Temperature ri is slower and the tendency to overshoot on temper ture is greater. As a result, the initial meltdown tak considerably more time, the temperature contr during the crystal pulling run is not quite as goo

nd it takes more time for the furnace to cool down dismantling temperature after the run.

From the standpoint of initial cost, a resistance urnace is usually somewhat more expensive than a omparable induction furnace. The reason is that a esistance furnace is usually housed in a somewhat nassive stainless steel container on which water-ooling tubes are brazed at various locations. As a esult, it is an expensive, though well built and urable, type of structure as compared with the mple induction furnace. The pulling mechanism in ither case would be the same. Rotation of the cru-ible in the case of the resistance furnace would be ifficult and is usually not attempted.

The usual type of resistance heating coil is a single-hase helix which draws a heavy single-phase load rom the power line, unbalancing the three-phase upply. Although this can be compensated for by perating three furnaces from three separate phases, is unlikely that all three furnaces would be shut own at the same time, so that there would still be eriods of unbalance. On the other hand, all induction units except very small ones are designed for three-phase operation.

Once a resistance furnace is built for a certain material, it is quite difficult to modify the furnace for new parameters. On the other hand, the induction furnace can be operated with different size melts and different temperatures with few if any problems with each change.

However, a major advantage of resistance heating over induction heating is in the cost of the generating equipment, an advantage that is partly overcome by the higher cost of the furnace in the initial installation. The actual operating cost of a resistance furnace is however, greater because replacement parts in the furnace are expensive and are rather frequently required and since meltdown and cooldown times are considerably longer, the operator cost is greater. Power consumption of an r-f generator is greater than a resistance furnace, but this differential is virtually negligible in practice. At one cent per kilowatt hour the power cost to pull a typical crystal using induction heating would be only about 50 cents.

High Speed Circuit Breakers

CARL DAVID TODD*

The normal fuse or circuit breaker does not act with sufficient speed to give adequate protection for some devices. For most cases a rather severe overload must occur before any protection is afforded due to the lack of precision in setting the trigger point. Utilizing the highly stable peak current of tunnel diodes, a high speed circuit breaker which offers protection for a ten percent overload may be designed. The elapsed time before the current is returned to the design level may be made under a microsecond, even for severe overloads. Additional features gained are stability with temperature and vibration, and the ability to trigger or reset the breaker from a remote point.

SOME CIRCUITS DEMAND HIGH SPEED operation if any degree of protection is to be provided. Ordinary fuses and circuit breakers require too much time efore they act, and the accuracy of the limit current alue leaves much to be desired. Since no sharply de-ned limit current exists, only severe overload pro-ection is afforded. By utilizing the highly stable peak urrent of tunnel diodes, a high speed circuit breaker nay be designed to be capable of protection from only 10 percent overload or less.

Other added features which will be described are emperature stability, low current protection below 00 microamperes, and the ability to reset by means f a trigger pulse if desired.

In the following sections of this article the circuit vill be described and a mathematical analysis will be presented. Results from laboratory tests of the circuits will also be given.

Senior Staff Engineer, Special Products Operations, Hughes emiconductor Division, Newport Beach, California.

Basic Circuit

The basic diagram of the tunnel diode circuit breaker is shown in Fig. 1. Assumed direction of currents are shown. All formulas and analyses are consistent with these assumptions. Transistor Q_1 is placed in series with the load and is controlled by the bias voltage across the tunnel diode. For load currents below the limit value, I_{LM}, the tunnel diode will remain in the low voltage state after the reset push button is depressed. Under this condition, voltage source, V_1, supplies enough base current, I_B, to saturate the transistor.

As the load current is increased, the current I_1, through the tunnel diode is also increased. If I_1 attempts to exceed the peak current I_P, of the tunnel diode, switching action to the high voltage state will occur. The voltage across the tunnel diode subtracts

from the supply voltage V_1 and may thus reduce the base current of Q_1 to a very low value or possibly even cause the emitter-base junction to be reverse-biased. With the base bias current removed, collector current ceases to flow and the load is disconnected from the supply voltages V_1 and V_2. Were it not for the presence of resistor R_2, the tunnel diode would switch back to the low voltage state as soon as the sum of the load current and I_B decreased below the valley current, I_V, of the tunnel diode.

Analysis

The circuit breaker fires when current I_1 attempts to exceed I_P of the tunnel diode. For the current flow assumed in Fig. 1:

$$I_1 = I_2 + I_E$$

$$= \frac{V_1 + V_2}{R_2} - I_B + I_L$$

or

$$I_{LM} = I_P + I_B - \left(\frac{V_1 + V_2}{R_2}\right)$$

The base current I_B must be chosen to saturate Q_1 up to the maximum load current, or

$$-I_B = \frac{I_{LM}}{h_{FE}}(1 + k)$$

h_{FE} here is the non-saturated value of the transistor current gain taken at a collector voltage, V_{CE}, and a collector current equal to I_{LM}. The constant "k" determines the degree of saturation produced in the transistor. For most transistors, a value of 0.5 is adequate for k, since this allows a 50 percent base overdrive. Should extremely low temperature operation (where h_{FE} decreases considerably for most transistors) be required, it may be necessary to use a slightly higher value of k.

For the circuit of Fig. 1, the value of I_B is given by the expression:

$$-I_B = \frac{+V_1 - V_F - V_{EB}}{R_1}$$

Zero base current will flow if V_F, the forward voltage of the tunnel diode is equal to the value of V_1. In silicon transistors (or less pronounced in germanium transistors), if the value of V_{BE} is less than a certain "knee" value, V_K, as shown in Fig. 2, conduction will be negligible. Thus it is only necessary for the sum of the tunnel diode forward voltage and V_K to be greater than V_1 in order to turn off Q_1.

The series voltage drop across the circuit breaker for values of load current below the maximum limit may be approximated by:

$$V_S = V_F - V_{CE\ (sat)}$$

where V_F here is less than V_P of the tunnel diode (usually some 50 mV for germanium tunnel diodes) and the $V_{CE\ (sat)}$ is measured at the current level of interest.

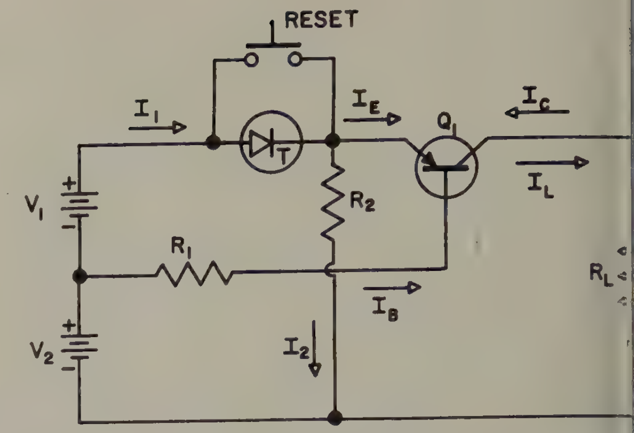


Fig. 1—Basic tunnel diode circuit breaker diagram

The value of I_{LM} will be slightly dependent on supply voltage, V. If the transistor used has a re tively high h_{FE} or if V_1 is derived from a const voltage source:

$$\theta = \frac{\%\ \text{change in}\ I_{LM}}{\%\ \text{change in}\ V} = \frac{1}{\frac{I_P}{I_2} - 1}$$

For most cases, I_P/I_2 will be greater than two, t causing θ to be less than unity. It is seen that h stability in the value of I_{LM} is obtained when the va of I_2 approaches I_V and the peak to valley ratio of tunnel diode is high.

If V_1 is not held constant or if the h_{FE} of the tr sistor is not high enough to neglect the base curre the value of θ will be slightly larger than that in cated above. In an extreme case it may be twice value given by the above equation. If wide variati in supply voltage are expected, V_1 should be re lated to some degree or difficulty may arise in ma taining the proper "on" and "off" conditions.

Variations in I_{LM} with temperature will be mai caused by changes in I_B as a result of a decrease V_{EB} of the transistor. This may be compensated by developing the voltage V_1 across a diode wh forward voltage changes in a similar manner.

Design

Normal requirements for a circuit breaker wo list a trigger current, I_{LM} and a supply voltage, (V_1 V_2). A complete design would thus consist of det mining the required value of I_P and I_V for the tun diode, the values of resistors R_1 and R_2, the port of the supply voltage to be used for V_1, and needed characteristics of transistor Q_1.

The first step must be the choice of tunnel di since the other component values will be somew dependent on the parameters of the tunnel diode.

The value of I_P must be greater than the maxim load current, I_{LM}, by an amount equal to the sum I_B and I_2. The minimum amount of I_2 allowable equal to the value of I_V of the tunnel diode. In m cases, the value of I_B will be only a small portion

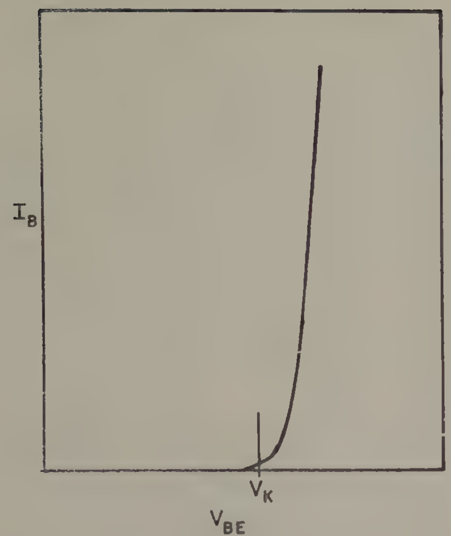


Fig. 2—Typical input characteristic of a silicon transistor.

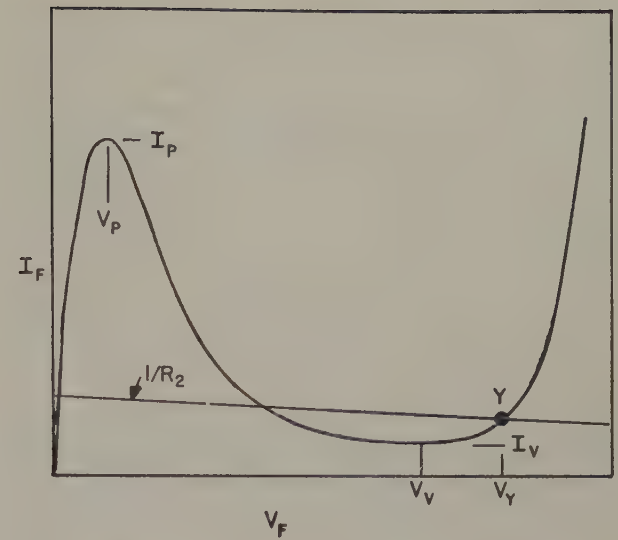


Fig. 3—Tunnel diode characteristic.

the value of the maximum load current. If I_B may then be temporarily neglected, the requirements of the tunnel diode are that the difference between the values of I_P and I_V be greater than I_{LM}. It is advisable to choose a tunnel diode such that this difference is at least 20 percent greater than I_{LM} so that accurate adjustment may be made in the final value of I_{LM} by controlling I_2.

The transistor used must possess a usable h_{FE} at the maximum load current. The non-saturated h_{FE} of the transistor at a collector current of I_{LM} should normally be 30 or better, though transistors with lower values of h_{FE} can be used. The voltage rating of the transistor must be in excess of the value of $V_1 + V_2$. If the design is for a zero base current after triggering, then the voltage breakdown to be considered is BV_{CEO}. However, if a reverse V_{BE} exists in the triggered state, the lower of the V_{PT} or BV_{CBO} will be the limiting value.

Leakage currents of the transistor will not normally be a problem particularly if the design is such as to provide the reverse V_{BE} in the triggered state. If high temperature operation at low currents is desired, silicon transistors should be used.

If high speed is one of the requirements of the circuit breaker, then the transistor must also be capable of high speed operation. Of particular concern are the storage time and turn off time of the transistor. It is interesting to note that even low speed audio transistors will allow faster circuit breaker action than that of normal fuses and circuit breakers.

The next discussion necessary is that of a choice of V_1. V_1 should be large enough to provide the required I_B when the tunnel diode is in the "off" or low voltage state, yet it should be less than the sum of the valley voltage of the tunel diode and the value of V_K as shown in Fig. 2. The effects of temperature on the value of V_K (approximately 2.5 mV decrease per centigrade degree) should definitely be considered.

Figure 3 shows the characteristic of the tunnel diode. Of particular interest in making the choice of V_1 are the voltages V_P and V_Y. V_P is the peak voltage of the tunnel diode and V_Y is the value of V_F for a practical bias point beyond the valley voltage. If a germanium transistor is used, it is convenient to make V_1 slightly less than V_Y of the tunnel diode. If a silicon transistor is used, it becomes more convenient to make V_1 slightly less than the sum of V_Y of the tunnel diode and V_K of the transistor input.

Gallium arsenide tunnel diodes exhibit a much higher valley voltage than germanium units. This allows a substantial reverve V_{BE} to be applied to a germanium transistor thus improving its breakdown voltage (unless V_{PT} is the limiting voltage for the transistor), its leakage current, and its switching speed. Two or more germanium tunnel diodes may be used in series with proper circuit modification to give a higher switching voltage.

The supply V_1 may be obtained from the main supply voltage by use of a voltage divider. If the supply voltage varies appreciably, it may be desirable to provide either a separate supply for V_1 or use a single zener diode regulator to provide a constant voltage from which V_1 may be derived.

Resistor R_1 should be selected to give the required base current for the transistor.

$$R_1 = \frac{V_1 - V_Y - V_{EB}}{-I_B}$$

V_P is the peak voltage of the tunnel diode. The value of V_{EB} used should be that value required to force the desired I_B with a current equal to I_{LM} flowing in the collector, at the lowest temperatures to be considered. The value of I_B required is a function of I_{LM} and the h_{FE} of the transistor as described previously.

The final step is to determine the value of resistor R_2. In order to assure locking once the circuit breaker has been tripped, the current I_2 must be maintained

at a level greater than the valley current of the tunnel diode. For the supply voltage levels normally used, this current will be very close to $(V_1 + V_2)/R_2$.

As suggested earlier, the tunnel diode should be chosen with an $(I_P - I_V)$ greater than the value of I_{LM}. Then, by adjustment of the value of I_2, a precise setting of I_{LM} may be obtained. R_2 may be calculated from the expression:

$$R_2 = \frac{V_1 + V_2}{I_P + I_B - I_{LM}}$$

It may be desirable to use an adjustable resistor for R_2 to obtain accurate control of I_{LM}. The resistor dial markings may be calibrated in terms of I_{LM}.

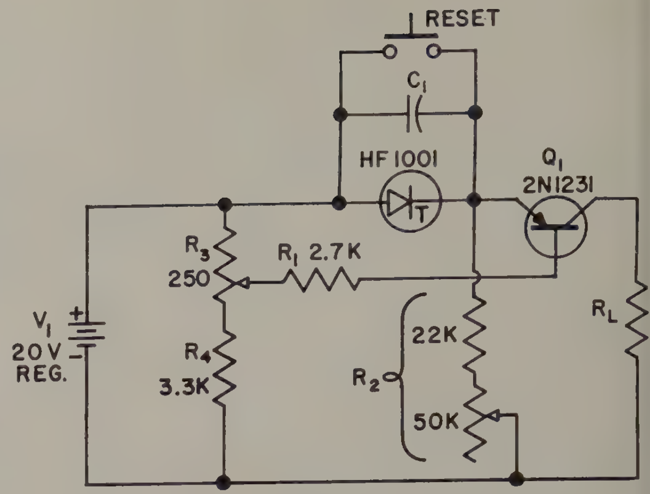


Fig. 4—One milliampere circuit breaker.

Practical Circuits

Using slight variations in the basic configuration of Fig. 1 can yield several useful circuits for current and voltage protection.

Figure 4 illustrates a simple low current circuit breaker which may be used when the supply voltage is regulated and where temperature excursions are not too severe. Proper choice of capacitor C_1 will prevent transients from tripping the breaker yet with an overall response time in the neighborhood of a microsecond. The actual speed of this circuit will be limited by the transistor, Q_1.

High speed circuit breaker action is often desired where the supply voltage is not regulated. For this condition, the circuit of Fig. 5 may be used. The tunnel diode must be chosen with I_P equal to the desired I_{LM}.

The use of a diode for developing the emitter-base bias voltage gives adequate stability with supply voltage variation and for considerable temperature changes. Two diodes and a resistor network may be used if Q_1 is a silicon transistor.

Locking action is obtained through the use of a resistor, R_2, shunting the collector. Normally Q_1 is in a saturated condition and the equivalent d-c collector-emitter resistance is much smaller than R_2. Thus, for all practical purposes, resistor R_2 is out of the circuit. Once the circuit breaker is tripped however, V_{CE} of Q_1 increases and current will flow through R_2. This current must be made greater than the tunnel diode's valley current for locking.

If protection is desired from overvoltage of the supply, it is only necessary to place a zener diode across the load resistor.

Another configuration for use with an unregulated supply is shown in Fig. 6. The dial for potentiometer R_5 may be calibrated directly in values of I_{LM}.

By additional circuit modification, the circuit breaker may be tripped or reset from a remote point by means of pulses. Self-resetting circuitry may be added such that as soon as the overload is removed, power will be restored. ■ ■

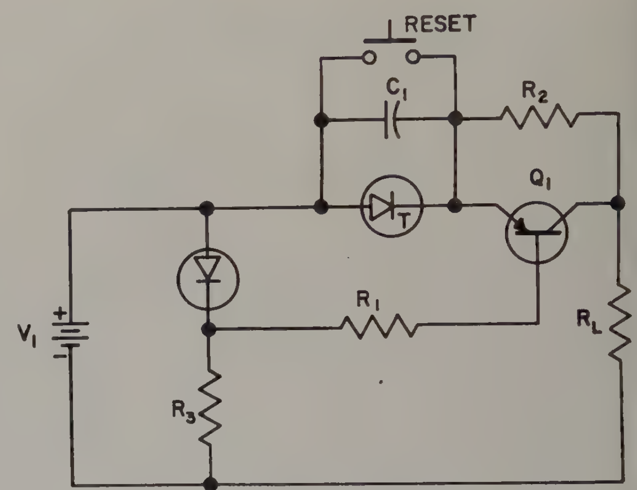


Fig. 5—High speed circuit breaker for unregulated supply.

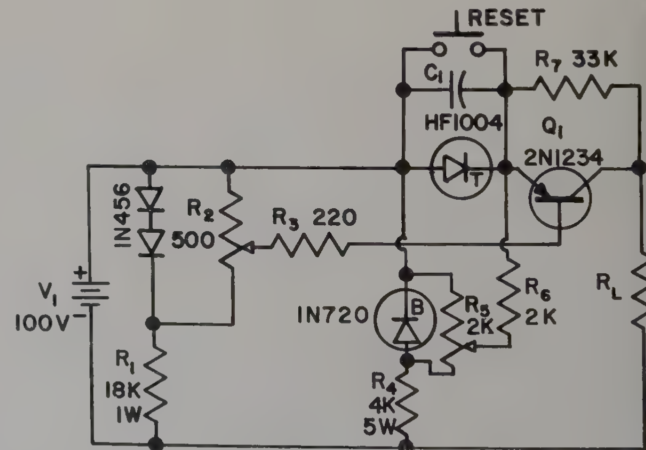


Fig. 6—Circuit breaker with adjustable trip current.

A Solid State 125-Watt Linear Power Amplifier

JAMES A. LOSTETTER*

The design of a very reliable 125 watt linear class "B" push-pull transistor amplifier, utilizing a unique common emitter common base compound connection which permits the use of higher than normal supply voltages is described in this article. The use of this compound connection makes it easier to select transistors to maximize amplifier performance, and because of the functional division of this connection, excellent overall thermal stability is obtained. The amplifier described is capable of being used as a "building block" in paralleled connections for higher power output. Experimental performance is given for transistor mounting base temperatures from 25°C to 70°C.

INCREASING DEMAND for transistor amplifiers with higher power outputs, higher frequency operation, and reliable operation from higher power supply voltages, has stimulated the development of this rather unusual high power amplifier. The compound circuit used in the amplifier described here, in essence, allocates the current gain function and the voltage gain function to separate stages as shown in Fig. 1.

As a consequence of this functional division, and if both transistors are fabricated by the same processing technique, the following statements apply:

1. Current gain, power gain, and frequency response of the compound circuit are primarily determined by characteristics of the common emitter stage.
2. Voltage capability and power capability of the compound circuit are determined by characteristics of the common base stage.

The characteristics in (1) and (2) above tend to militate against each other when all must be combined in a conventional common emitter stage. Thus, by using the compound circuit, it is easier to select or design transistors to maximize performance in all categories. The compound circuit is also more reliable than a conventional common emitter circuit because of its inherent immunity to the alpha unity breakdown voltage condition, and because "thermal runaway" will be governed by the common emitter stage which operates at a very low voltage.

Although the following discussion is limited to the operation of a Class "B" push-pull linear power amplifier, the use of this compound connection in switching or Class "A" linear modes of operation should prove to be equally advantageous.

* Minneapolis-Honeywell Regulator Company, Semiconductor Products, Minneapolis, Minnesota.

The design objectives of this amplifier are as follows:

1. 125-watt power output.
2. Total harmonic distortion less than 5% over entire audio spectrum at maximum power output.
3. 60% efficiency, or greater, at maximum power output.
4. Minimum use of feedback (high over-all gain).
5. Operation at mounting base temperatures as high as 70° C.
6. Operation from supply voltages in the 30- to 40-volt range (allowing for voltage doubling Class "B" push-pull operation).
7. Amplifier configuration capable of being paralleled for higher power output.

Design Criteria

To fulfill the efficiency objective, Class "B" push-pull operation must be used. Since both sides of this type circuit are identical, the following discussion and description will be limited to one side of the amplifier, unless otherwise indicated.

A. Common Base Stage

To achieve a power output of 125 watts with maximum efficiency (minimum I^2R losses in the output

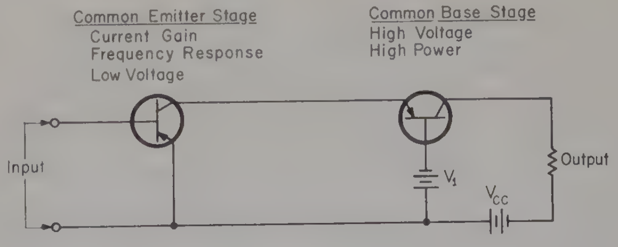


Fig. 1—Basic compound circuit.

transformer and circuit components), and to use a minimum number of transistors, selection of a high supply voltage is desirable. This will permit operation at lower current levels. Conversely, if too high a supply voltage is used in a voltage doubling push-pull circuit, it is difficult to obtain transistors with the required high voltage capability. With these influencing factors in mind, a nominal supply voltage of 40 volts was selected to power this amplifier.

Very low input impedance is characteristic of a common base connection. It is in the order of 0.1 to 0.2 ohms for the "power" type transistors considered here. At full drive, the peak voltage drop across the emitter base junction of the common base transistor is only about one volt. Thus, it is possible to operate the common emitter stage at a low voltage level. Auxiliary bias voltage for the input loop is best inserted in the base lead of the common base stage where the current magnitude is much lower than the output current.

This auxiliary bias voltage (V_1) subtracts from the collector supply voltage (V_{CC}) when determining the peak voltage which the common base stage will deliver to the load without clipping. Therefore, with $V_1 = 4$ volts the peak load voltage (V_L) is:

$$V_L = V_{CC} - V_1 = 40 - 4 = 36 \text{ volts}$$

With the peak voltage and maximum power output (P_{out}) known, the peak collector current (I_{MAX}) will be:

$$I_{MAX} = \frac{2\,P_{out}}{V_L} = \frac{2 \times 125}{36} = 6.95 \text{ amperes}$$

The effective load resistance (R_{CB}) for each common base transistor will be:

$$R_{CB} = \frac{V_L}{I_{MAX}} = \frac{36}{6.95} = 5.18 \text{ ohms}$$

In Fig. 5, choke coupling is used and the load resistance of 20.72 ohms is connected across the entire choke. A multi-tapped choke can be used to couple the load to the amplifier if the load impedance is not greatly different than the required collector-to-collector impedance of the common base transistors. Conventional transformer coupling may also be used. Generally, a choke offers the advantages of simplicity, higher efficiency, smaller size, and lower cost.

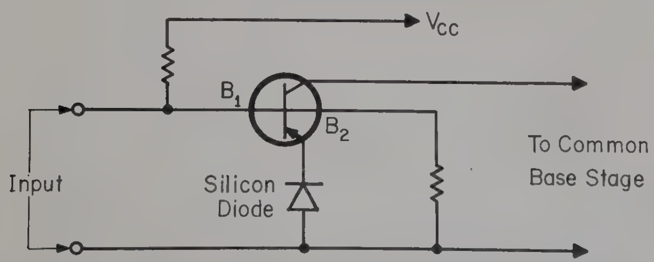


Fig. 2—Basic common emitter stage with tetrode biasing.

In class "B" operation, average collector power dissipation is maximum when the amplifier is driven such that peak load voltage is 63.7% of its value at full drive ($K = .637$ in Eq. 1). At this point, the amplifier efficiency is equal to 50%. The average collector power dissipation (P_C) for one common base transistor during the conduction half cycle of a sine wave is:

$$P_C = \frac{V_L^2}{R_{CB}} \left[\frac{2}{\pi} K - \frac{K^2}{2} \right] \quad (1)$$

$$P_C = \frac{(36)^2}{5.18} \left[\frac{2}{3.14} \times .637 - \frac{(.637)^2}{2} \right]$$

$$P_C = 50 \text{ watts}$$

Since this transistor is turned off for the other half cycle, the average power dissipated by the collector junction during a complete cycle is equal to half this value, or 25 watts.

The transistor selected for the common base stage must have the following capabilities:

1. 6.95 amperes collector current.
2. 72 volts collector-to-base voltage.
3. 25-watts average collector dissipation at a mounting base temperature of 70° C. (This requirement, along with maximum junction temperature rating, determines maximum permissible thermal resistance).

A 3N48 or 3N52 power transistor exceeds these requirements. Therefore, either can be used for a conservative design.

A collector dissipation of about 3 watts for each common base transistor is obtained in standby, or zero signal conditions. This is the result of a small forward bias (about 85 ma d-c) established in the common emitter stage to minimize cross-over distortion in the compound connected amplifier (Note: the collector currents of the common emitter and common base stages are very nearly equal).

B. Common Emitter Stage

The transistor selected for the common emitter stage must meet these requirements:

1. Linearity—less than 5% distortion.
2. Stability—operate reliably at mounting base temperatures to 70° C.
3. Current gain and power gain—high gain to 7 amperes.
4. Frequency response—good over entire audio range.

A 3N47 or 3N51 power transistor fulfills these requirements when used as shown in Fig. 2. A separate low voltage bias supply is required by the common emitter stage. As shown in Fig. 5, this supply (V_1) must furnish the peak voltage drop (V_{D5}) across diode D_5, plus the peak forward voltage drop (V_{EB}) across the emitter-base junction of the common base transistor, plus the saturation voltage, ($V_{CE(SAT)}$) of the common emitter transistor, as well as the neces-

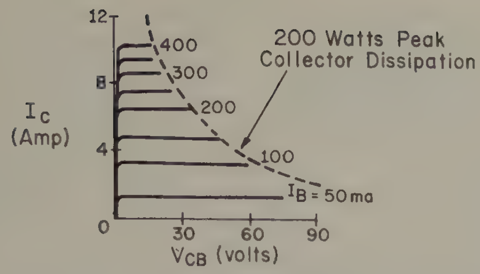


Fig. 3—Composite output characteristic.

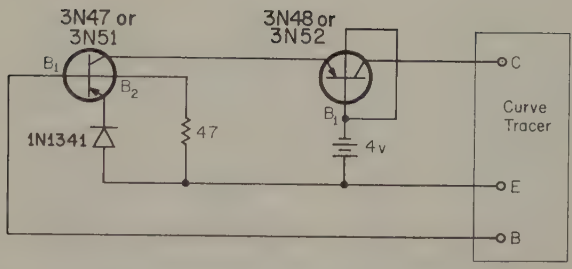


Fig. 4—Composite characteristic test circuit.

sary working voltage (V_{CE}) across the collector-to-emitter of this transistor.

Therefore, the minimum voltage for V_1 will be:

$$V_1 = V_{D5} + V_{EB} + V_{CE\,(SAT)} + V_{CE}$$

$$V_1 = 1.1 + .7 + .5 + 1.0 = 3.3 \text{ volts}$$

Supply V_1 must only be capable of supplying the base current of the 3N48 common base transistor. Typical current gain (h_{FE}), for a 3N48, at 7 amperes collector current, is 25. Therefore, the peak current (I_1) requirement for V_1 will be:

$$I_1 = \frac{I_{MAX}}{h_{FE}} = \frac{7}{25} = .280 \text{ amperes}$$

Establishing the 85 ma d-c quiescent collector current which is used to reduce cross-over distortion, is accomplished with the stable voltage divider type of biasing network formed by R_3, R_1 and the d-c resistance of half the secondary of transformer T_1. The value of R_3 may have to be changed to maintain the value of I_c if a transistor with much different gain is used. As shown in Fig. 5, the diodes D_1 and D_2, in series with base one of transistor Q_1, block reverse drive during the off half cycle. This effectively reduces high frequency distortion.

Meeting the stability, linearity, and frequency response requirements placed on this stage is enhanced by tetrode biasing of transistor Q_1, that is, by applying the forward bias and input drive signal to base one and a reverse, or positive, bias to base two. This reverse bias, applied to B_2 of Q_1 through potentiometer R_5, is obtained from the forward voltage drop across D_5, a silicon power diode. This method of biasing permits one to balance or match gains of the two transistors. By adjusting R_5 while observing the total harmonic distortion of the amplifier, it is possible to obtain a sharp null condition, one of minimum distortion (balanced output currents from Q_1 and Q_2). If low distortion and extended frequency response is not a design objective, then diodes D_1 through D_5 and potentiometer R_5 may be omitted from the circuit.

Balanced, out-of-phase drive signals to B_1 of Q_1 and Q_2 are obtained from the center-tapped secondary of transformer T_1 shown in Fig. 5.

C. Composite Circuit Output Characteristics

Figure 3 shows a "family" of collector characteristic curves for the composite common emitter, common base circuit. These characteristic curves were observed for a current drive condition, using a curve tracer to sweep the collector-to-base of a 3N48 or 3N52 with a 60-cycle half sine wave voltage. The test circuit is shown in Fig. 4. The absence of an alpha unity breakdown voltage condition in these characteristic curves confirms one of the main advantages of this composite circuit. Normally this breakdown condition is very conspicuously displayed in the form of sharply rising collector current in the region of 30 to 60 volts, in conventional common emitter collector characteristics. With a constant emitter current, the voltage applied to the collector base junction of a common base stage can be safely extended into the region of collector multiplication where alpha exceeds unity (collector current is greater than emitter current). Therefore, the voltage capability of the composite circuit is limited only by the breakdown voltage of the transistor collector diode, itself, or the reach through voltage, whichever is lower. Because this composite circuit has the same voltage phase reversal characteristics as a conventional common emitter circuit, negative local feedback can be used in conventional ways.

Experimental Results

A. Dynamic Performance

To measure the performance of the two-stage amplifier, the primary of the driver transformer, T_1, is directly connected to an audio oscillator. The amplitude of the oscillator is adjusted to obtain the desired power output from the amplifier. The following conditions exist for the circuit shown in Fig. 5 and for the performance listed in Table I.

V_1 = 4 volts d-c
V_{CC} = 40 volts d-c
V_{CB} = 36 volts d-c
R_L = 20.7 ohms
I_{CQ} = 180 ma d-c (total for all transistors)
Frequency = 400 cps (unless otherwise stated)

No special selection of transistors is necessary for the performance shown in Table I.

Total harmonic distortion decreases as a function of increasing frequency over the range shown in

Table I—Performance with no feedback

Power Output	125 watts	50 watts
Power Gain	24.3 db	25.5 db
Cutoff Frequency, 3 db down point	14 kc	13 kc
Total Harmonic Distortion		
a. 400 cps	3.2%	3.6%
b. 7.5 kcps	1.8%	2.5%
Efficiency	70%	42%

Fig. 6. This is observed in the output wave shape as decreasing cross-over distortion as a function of frequency, and is made possible by the blocking diodes in the input drive circuit. A graphical display of total harmonic distortion versus power output at 100 cps and 7.5 kc is shown in Fig. 7. The increasing distortion characteristic at lower power output, and lower frequency, is the result of more cross-over distortion. This effect can be reduced by increasing the quiescent current. However, distortion will then increase slightly at higher power levels. The optimum condition depends on the specific requirements of a particular application.

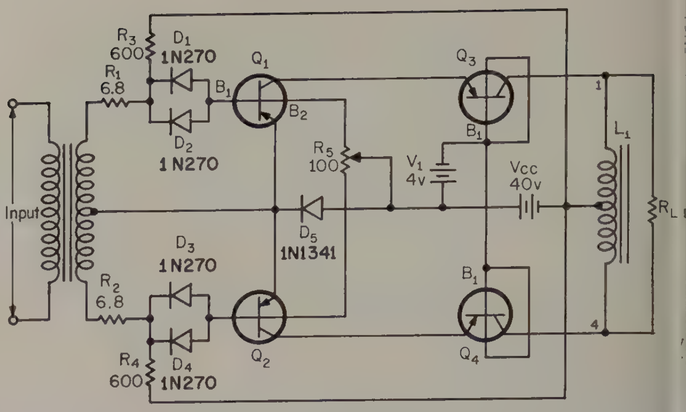
Figure 9 shows the distribution of total harmonic distortion at 125 watts power output and an operating frequency of 1 kc. The third harmonic is dominant. The second harmonic is approximately half the amplitude of the third harmonic, and shows the result of some even order harmonic cancellation obtained by balancing the output currents with potentiometer R_5, as previously explained.

B. Higher Power Parallel Operation

Applying paralleling techniques to the circuit shown in Fig. 5 makes it possible to obtain substantially higher output power. As shown in Fig. 8, doubling the number of transistors doubles the output power capability. The performance of this paralleled circuit is comparable to that of the 125-watt circuit shown in Fig. 5.

The problem of parallel operation of transistors is one of current division. With the compound connection, this problem is confined to the common emitter stage. Individual series base and emitter resistors are used in these stages, as shown in Fig. 8, to help equalize the current through each transistor. Each collector of the common emitter stage is separately connected to the emitter of its respective common base stage.

The increased demands on the d-c power supplies, output choke (or transformer), input transformer, or drive, due to parallel operation, are straightforward design problems.



Q_1 and Q_2 = 3N47 or 3N51 Honeywell Transistors
Q_3 and Q_4 = 3N48 or 3N52 Honeywell Transistors
(Triode connected)
T_1 = Input transformer—driving source impedance should be 10 to 20 ohms—d-c resistance in range of 2 to 4 ohms
L_1 = Output choke or transformer as required. Amplifier is designed to deliver 125 watts into 20.72 ohms collector-to-collector of Q_3 and Q_4 (5.18 ohms collector-to-center tap)

Fig. 5—125—watt class "B" push-pull transistor amplifier.

C. Thermal Behavior

Because of the critical relation between electrical and thermal problems in transistor amplifier design, both must be recognized and solved if the performance stated in the amplifier objectives is to be realized with a reasonable degree of reliability. While operating the two-stage 125-watt amplifier under the most severe conditions, i.e. maximum collector dissipation and at a mounting base temperature of 70° C, the only performance degradation noted was a 0.8 db reduction of power gain.

The tabulation, (Table II), of total amplifier quiescent (no signal) current, at the various transistor mounting base temperatures, is a good indication of the thermal stability of this design. All transistor mounting base temperatures were maintained at the indicated values. These results were obtained *without* the use of emitter degeneration resistance to improve stability.

Thermal isolation of the common emitter stage from the higher dissipation, heat generating, common base stage will improve the over-all operating point stability. This is because the common base stage is stable, having no amplified leakage current, and relies on the common emitter stage to establish its quiescent col-

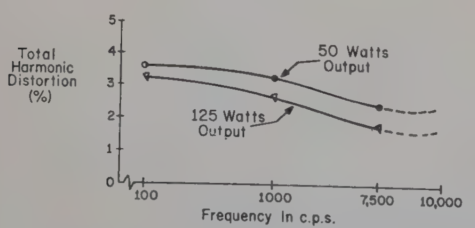


Fig. 6—Total harmonic distortion vs. frequency.

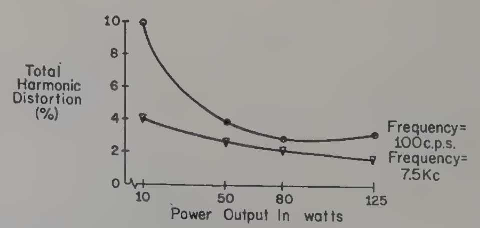


Fig. 7—Total harmonic distortion vs. power output.

Table II

Total Amplifier No Signal Current	Transistor Mounting Base Temperature
170 ma d-c	25°C
190 ma d-c	40°C
224 ma d-c	50°C
260 ma d-c	60°C
310 ma d-c	70°C

lector current. Therefore, if the common emitter stage can be made very stable, essentially a constant current source, the quiescent current for the entire circuit will remain nearly constant, even though the common base stage is exposed to higher junction temperatures. The fact that the common emitter stage operates at very low voltage is a tremendous advantage in achieving stability and freedom from thermal runaway. However, the maximum junction temperature limits of the common base transistor must still be observed.

D. Power Supply Requirements

To power the experimental amplifier, a 4-volt battery, and a 40-volt battery, are required for V_1 and V_{CC}, respectively. V_1 supplies the base current for transistors Q_3 and Q_4 which is about 280 ma peak. V_{CC} supplies the 6.95 ampere peak collector current of these stages. Both voltages can be obtained from a-c operated supplies provided they are well filtered, well regulated, and have relatively low impedance. If operation from a single power source is desired, one of arrangements shown in Figs. 10, 11 and 12 may be used for V_1.

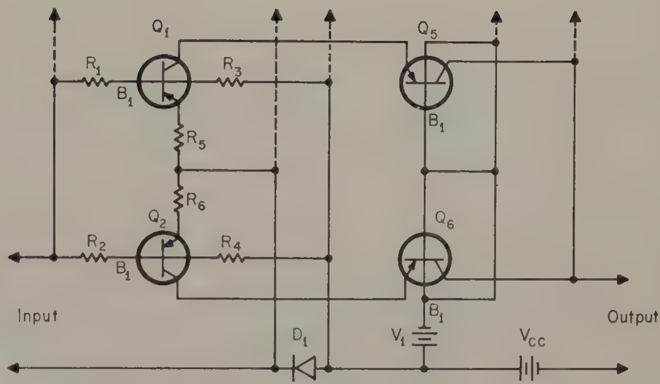
In Fig. 11, V_1 is obtained from the combined forward voltage drops across the silicon diodes. Because these units operate only in the forward direction, their voltage rating can be very low.

Conclusions

A circuit has been described which should find a wide range of use in applications where stable high power output is required over a fairly wide temperature range. The basic common-emitter common-base compound connection described combines the advantages of both configurations, pushing the operating voltage capability of germanium power transistors to a new high without the use of series operation. The basic compound circuit described is also more reliable than a conventional common emitter circuit, if each is operated under the same conditions, and improved frequency performance is possible. The amplifier discussed is highly efficient, exhibits good power gain, and delivers a high power output with low harmonic distortion over a wide range of frequency. Through the use of the paralleling techniques discussed, an amplifier with extremely high power output may be designed.

Acknowledgment

Recognition is given to Mr. Joseph Maupin for encouragement and criticism during the preparation of this article. ■ ■



R_1, R_2 = 1 ohm
R_3, R_4 = 47 ohms
R_5, R_6 = 0.1 ohms
V_1 = 4 volts d-c
V_{CC} = 40 volts d-c
Q_1, Q_2 = 3N47
Q_5, Q_6 = 3N48 (triode connected)

Fig. 8—250-watt amplifier parallel operation (only one side of circuit shown).

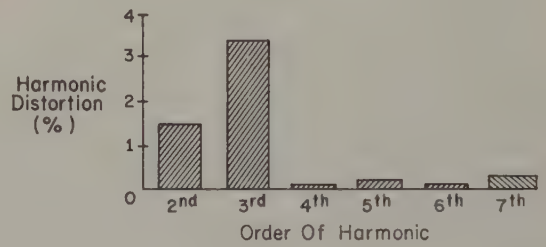


Fig. 9—Distribution of total harmonic distortion at 125 watts—1 kcps.

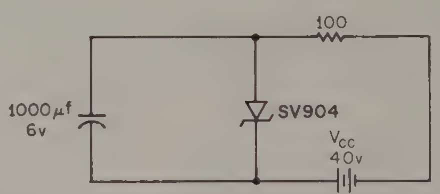


Fig. 10—Zener diode circuit for V_1.

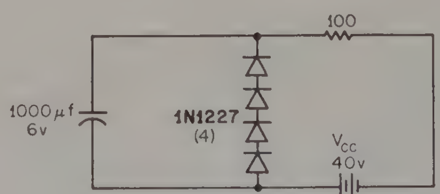


Fig. 11—Series string silicon diode circuit for V_1.

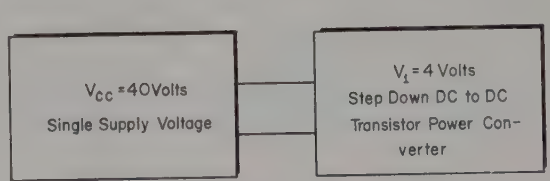


Fig. 12—D-C power converter circuit for V_1.

A Study of Gain Control In Audio Amplifiers

J. HEINCHON*

In some low frequency applications it is desirable to be able to control the gain of the amplifier electrically in order to incorporate an *agc* system. It is usually desirable that the frequency response not vary over the gain control range. Several methods of gain control which can be utilized with an *agc* circuit were investigated. These include changing the operating point and using diodes or transistors as resistances which are variable with voltage derived from an *agc* circuit. The most practical means of obtaining the desired control in a low frequency amplifier is through the use of feedback using a particular type transistor. The output impedance of the selected transistor should vary with an *agc* voltage such that frequency response remains relatively constant. Such a transistor which provides approximately 30 db of *agc* range with little change in response, is described herein. Several other *agc* circuits are described along with some of their advantages and disadvantages.

IN SOME LOW FREQUENCY CIRCUITS it is desirable that the gain control of an amplifier be accomplished automatically by some source of voltage derived from an automatic gain control (agc) circuit. A typical application is in a dictaphone circuit where the best recording is obtained when the output of the low frequency (audio) amplifier is not greatly affected by the intensity of the speaker's voice (input).

The agc control voltage for the amplifiers discussed herein may be derived from various sources but in this study, the interest lies primarily in the control of gain.

The transistors described as low frequency units, MADT® units and MAT® units are, respectively, 2N223's or 2N224's, T1692's and 2N393's.

Methods of Gain Control

A. Changing the Operating Point

With an agc voltage applied directly to the base of a low frequency amplifier as shown in Fig. 1, the d-c operating point of the amplifier is changed thereby changing the device gain. The response of the amplifier broadens proportionally with the applied agc voltage (see Fig. 7) because of the operating point change. A second disadvantage with this system, in addition to the change in response with applied agc voltage, is that the power handling capability of the amplifier decreases as the cutoff point is approached.

B. Use of Diodes as Variable Resistance Elements

Since diodes have resistance characteristics which vary with the voltage across them, they can be utilized in a circuit as variable resistances. Diodes, however, have at least one inherent disadvantage in that for all but extremely small signals the diode resistance will follow the signal. The variation in resistance with the signal will create a distorted output. For this reason diodes were not extensively investigated for use in low frequency gain control circuits.

Some diode circuits which might be used with extremely small signals are described below.

1. A Diode as a Variable Load Resistance

In the circuit of Fig. 2, a diode is utilized as a variable load resistance; its resistance is dependent on collector current. Since the diode resistance, in a forward biased state, is low for practical values of collector current, the load resistance, R_L, must also be made low so that small changes in diode resistance will affect the total load of the amplifier sufficiently to cause a large enough change in gain. The required low value of load resistance will not permit optimum gain to be derived from this configuration.

2. A Diode as a Variable Shunt Resistance

In the circuit of Fig. 3 a diode is utilized as a variable shunt resistance; the shunt resistance is determined by the magnitude the agc voltage applied.

3. A Diode as a Variable Feedback Resistance

In the circuit of Figure 4, a diode is utilized as a variable feedback resistance. This circuit appears to be the most useful diode circuit.

C. Feedback to Provide Gain Control

Although there are many possible methods of obtaining gain control, the method which appears to be the most useful for this type of amplifier is feedback. In feedback circuits, part of the output power is returned to the input in such a manner as to increase the output power (positive or regenerative feedback) or to decrease the output power (negative or degenerative feedback). In agc circuits, degenerative feedback which can be controlled by the output signal amplitude is the type of feedback used.

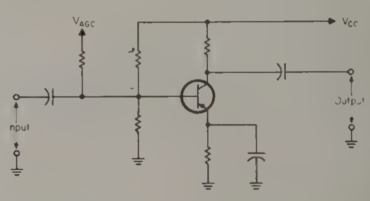


Fig. 1—Low frequency amplifier with agc voltage applied directly to its base.

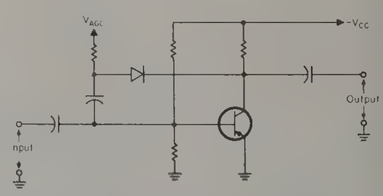


Fig. 2—Low frequency amplifier utilizing a diode as a variable load.

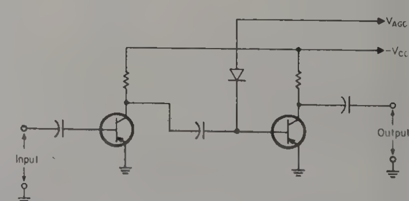


Fig. 3—Low frequency amplifier utilizing a diode as a variable shunt resistance.

* Applications Engineer, Philco Corporation, Lansdale Division, Lansdale, Pennsylvania

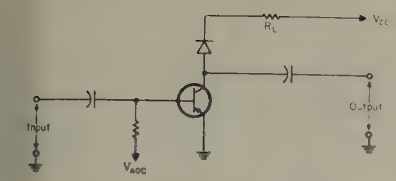


Fig. 4—Low frequency amplifier utilizing a diode as variable feedback resistance.

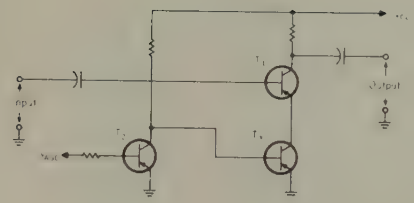


Fig. 5—Low frequency amplifier utilizing three transistors one of which acts as a variable feedback resistor.

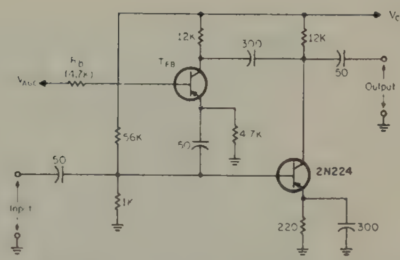


Fig. 6—Collector to base feedback using a transistor as the variable feedback resistance.

Resistive Feedback

With resistive feedback, gain and frequency response are affected by the amount of feedback introduced. The amount of feedback is commonly expressed in terms of the resulting decrease in amplification. As an example, 20 db of feedback means that the gain of an amplifier with feedback is 20 db less than the gain of an amplifier without feedback.[1] As the gain of an amplifier is decreased with feedback the frequency response broadens. Thus, the gain of such an amplifier decreases less at the extremes of the response curve resulting in effectively less loop feedback at these extremes than at the center. The net results is a cumulative action which results in additional broadening of the response with increased agc. The increase in bandwidth of the amplifier can be explained mathematically as follows.

The voltage gain of an amplifier, with feedback is:

$$G = \frac{A}{1 - \lambda A}$$

where G is the overall gain of the amplifier, A is the gain of the amplifier without feedback and λ is the fraction of the output which is fed back to the input. For degenerative feedback, λA is negative and the sign must be considered. The quantity $|\lambda A|$ is commonly termed the feedback factor. The expression for the overall gain of the amplifier becomes:

$$\frac{A}{1 + |\lambda A|}$$

and as $|\lambda A|$ becomes much greater than unity, $1 + |\lambda A|$ approaches $|\lambda A|$ making the overall gain expression:

$$G \cong \frac{A}{|\lambda A|} = \frac{1}{\lambda}\ ;\ |\lambda A| >> 1$$

This is no longer dependent on the gain of the amplifier without feedback. Since λ, in resistive feedback, is a resistance ratio which is independent of frequency, the gain of an amplifier with large amounts of resistive feedback is substantially independent of frequency; the result is a broad frequency response.

[1] Terman, F. E., Electronic & Radio Engineering, Fourth Edition McGraw-Hill Book Co., Inc., 1947, P. 375

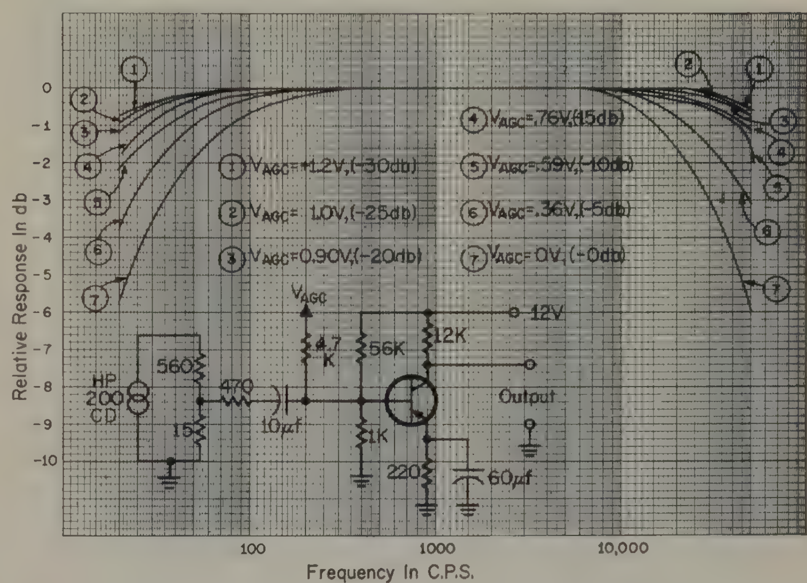


Fig. 7—Response of amplifier with agc voltage applied directly to its base. The agc voltages indicated are all negative. Note also that the quantity shown in parenthesis indicates the number of db to be subtracted from these curves in order to obtain the actual curves.

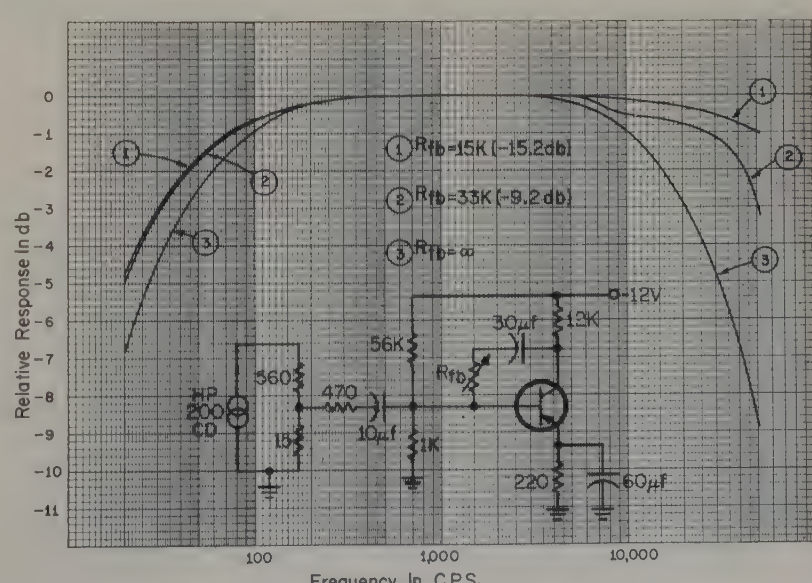


Fig. 8—Response of amplifier with resistive feedback.

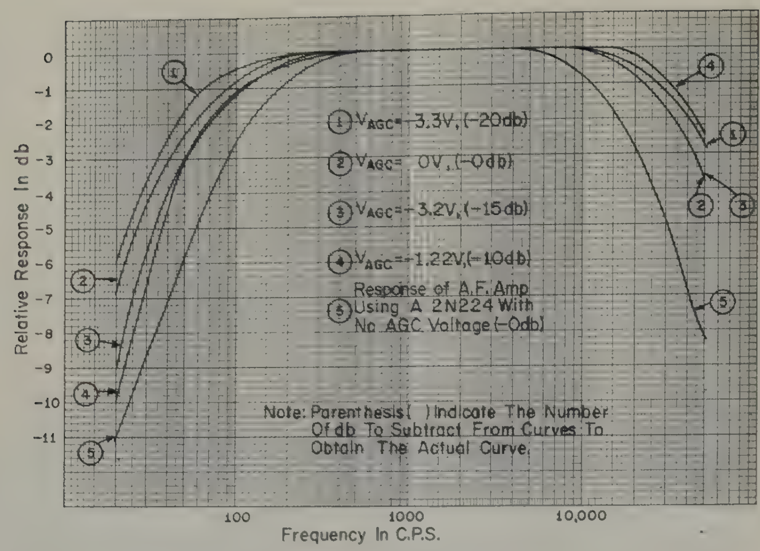


Fig. 9—Response with MADT as feedback component and a 12K load.

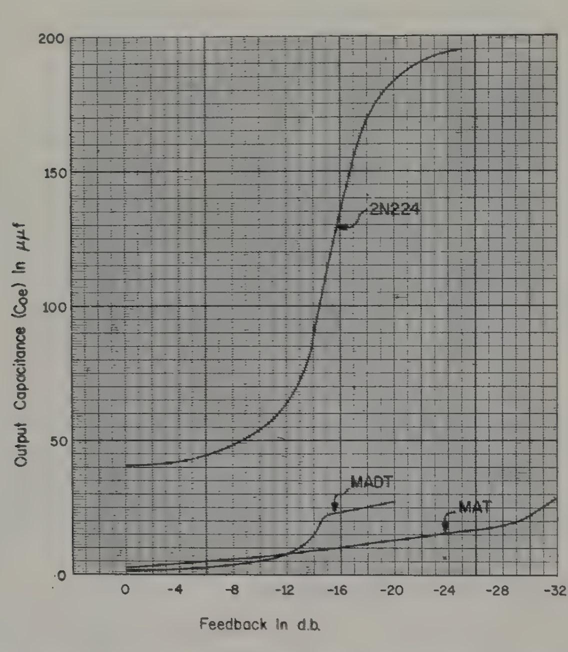


Fig. 10—Output capacitance for the three types of transistors used in the feedback circuit of Fig. 6.

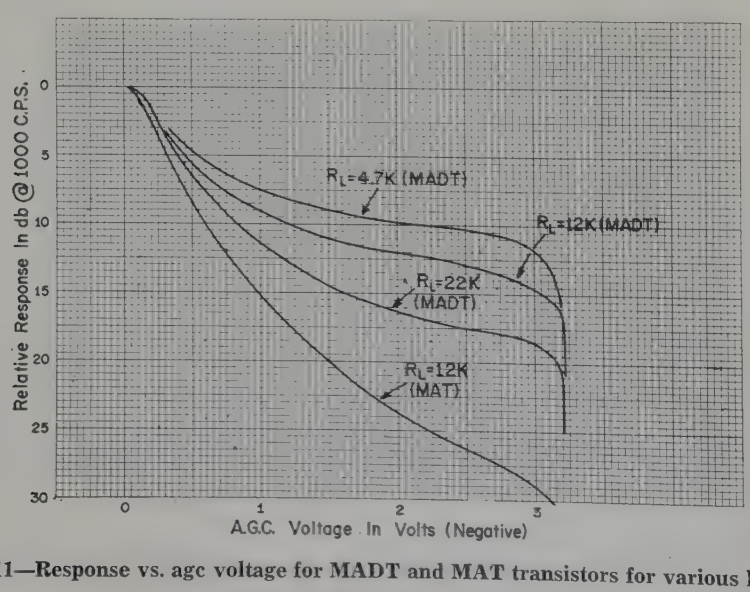


Fig. 11—Response vs. agc voltage for MADT and MAT transistors for various loads.

Transistors as Feedback Resistances

The response of an amplifier wit[h] relatively good low frequency charac[c]teristics does not change much at low frequencies with increased feedback. However, it does vary substantially a[t] high frequencies with relatively pur[e] resistive feedback. (See Fig. 8) I[t] should be noted that in drawing a[ll] response curves the amount of feedbac[k] at the midband frequency was added i[n] order to facilitate comparison of th[e] curves. The number of decibels adde[d] is indicated on each curve.

Since the output capacitance and re[sistance] of a transistor varies with op[erating] point, it may be used as [a] variable feedback component.

In the circuit of Fig. 5, three transis[tors] are utilized in a low frequenc[y] amplifier with feedback and agc ampli[fication]. In this circuit, T_1 is the low frequency amplifier, T_3 acts as an un[bypassed] emitter resistance, providin[g] variable degenerative current feedback and T_2 is an agc amplifier. Biasing mus[t] be provided for T_3 in order that its re[sistance] be low with no agc voltag[e] applied. In order to minimize resistanc[e] and degeneration with no agc voltag[e] applied, T_3 should be in saturation. A[s] agc voltage is applied, the resistance o[f] T_3 increases, increasing feedback an[d] decreasing gain. The most significan[t] disadvantage to this circuit, however, i[s] that power is required to keep T_3 in saturation even with no agc voltage ap[plied]. The biggest advantage to this cir[cuit] is the fact that the agc voltage re[quirement] is low becau[se] of the ag[c] amplifier. Depending upon the powe[r] available from the agc source, it ma[y] be possible to eliminate the agc am[plifier], T_2.

In the circuit of Fig. 6, an MAD[T] transistor (Philco T1692) was used a[s] the feedback component (T_{FB} in th[e] circuit). The response of the amplifie[r] with various amounts of feedback i[s] shown in Fig. 9. This curve also show[s] the response of a low frequency tran[sistor] (2N224) with no agc voltage applied to it. A comparison of the curve[s] for the low frequency transistor and fo[r] the MADT transistor with no agc applied is essentially a comparison of the output capacitance (C_{oe}) of the two units. The low frequency unit has a much higher output capacitance tha[n] the MADT for all degrees of feedback. A comparison of the output capacitances of the 2N224, the MADT and the MAT transistors is shown in Fig. 10. From these curves it is evident why the high frequency response of the low frequency unit is not as good as tha[t] of the MADT. The low frequency comparison between the low frequency unit and the MADT indicates that the output resistance (r_{oe}) of the 2N224 i[s] higher than the output resistance of the MADT with no feedback.

As agc voltage is applied to the bas[e] of the MADT, introducing feedback, th[e] high frequency response increases du[e] to the decrease in output resistance o[f] the transistor. The output capacitanc[e]

hange is slight with low amounts of eedback. As saturation is approached, owever, the output capacitance in-reases rapidly causing the response to ecrease. After the transistor is satu-ated, the output capacitance increases lowly again and the change in output esistance is again the prime factor in etermining the increase in response. he output, however, is distorted due o the changing output impedance with ignal. Figs. 9, 10, and 11 show pre-isely what is happening as feedback is ncreased.

With the MADT as the feedback omponent in the circuit of Fig. 6, if nore feedback is desired a larger value f load resistance can be used. Fig. 11 llustrates the amount of useful feed-ack which can be obtained with arious low frequency amplifier loads. When the agc voltage reaches approxi-nately three volts the MADT becomes aturated as indicated by the rapid ownward bending of the curves. After aturation is reached, the output im-edance changes with signal and the mount of feedback varies with the ignal which introduces distortion in he amplifier.

An important factor in determining ow much feedback can be obtained s the saturation resistance of the feed-ack transistor; but since the current s limited by the 12K load, a good neasure of the saturation resistance is he collector to emitter saturation volt-ge ($V_{CE\ SAT}$). In the circuit used, V_{CE} nust be less than 0.1 volts ($R_{feedback} \approx$ 00 ohms) for approximately 30 db of eedback which is less than $V_{CE\ SAT}$ for he MADT type transistor. A compari-on of the collector to emitter voltage or the MADT and MAT type transis-ors is shown in Fig. 12 as a function of gc voltage. Useful control of gain is btained until the curves in Fig. 11 turn n a vertical direction. The curves indi-ate that the greatest control range for he MADT can be obtained with a 22K udio frequency load resistance.

An MAT transistor has an output apacitance similar to that of the MADT s shown in Fig. 10 but it has a much ower saturation voltage (Fig. 12). The ypical saturation voltage of the 2N393 MAT transistor is .05 volts which al-ows more feedback. The response curve f the amplifier using a 2N393 transistor s the feedback component (Fig. 13) ndicates that there is little variation in he response between 0 db and 30 db f feedback.

Fig. 11 shows the range of feedback which can be attained with the same ange of voltage that was used with he MADT as the feedback component.

The effective low frequency amplifier oad is the parallel combination of the ollector load resistances of both the mplifier and the feedback transistors. The feedback transistor load, however, vas kept fixed at 12K ohms for all the neasurements. This 12K resistor de-ermines the current at which the feed-ack transistor saturates. The relative esponse versus agc voltage for the

(Continued on page 53)

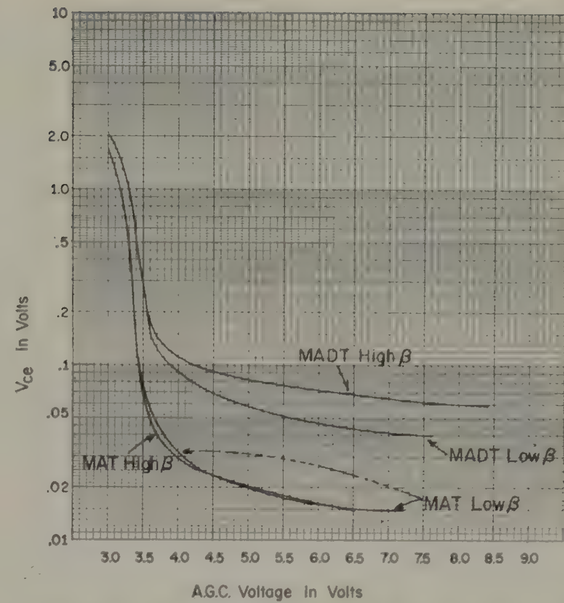


Fig. 12—AGC voltage vs. V_{CE} for high and low d-c beta MADT and MAT transistors in the feedback circuit.

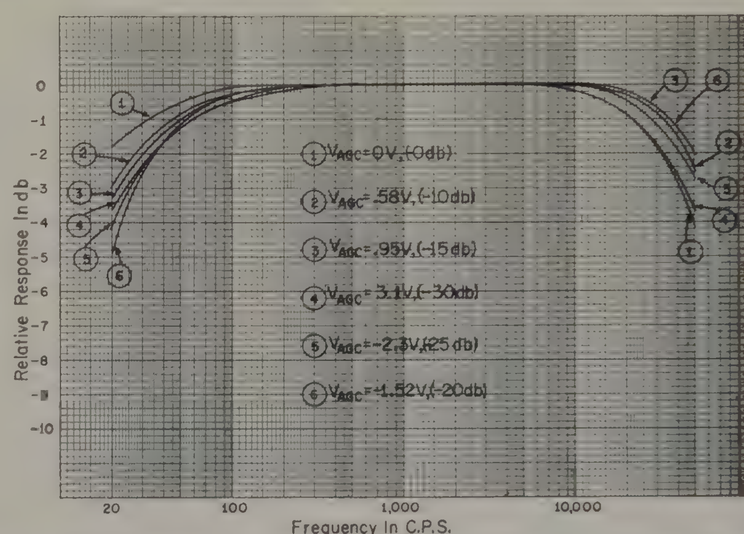


Fig. 13—Response using an MAT as the feedback transistor and a load of 12K.

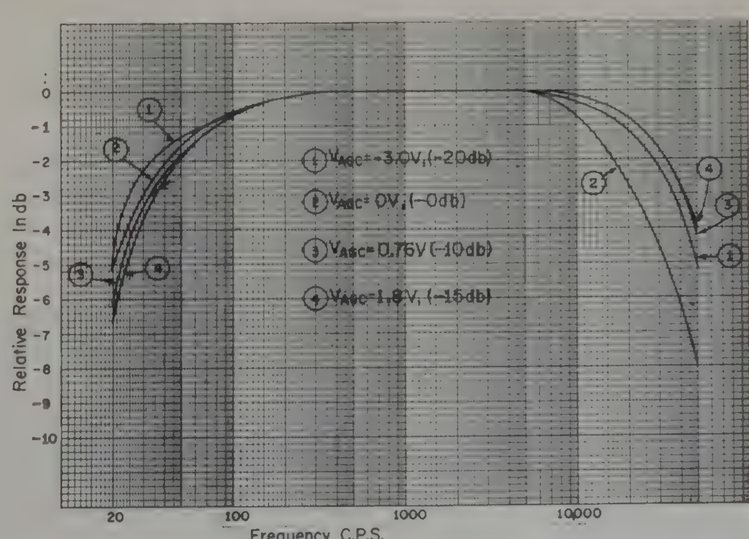


Fig. 14—Response using an MAT as the feedback transistor and a load of 2.2K.

PATENT REVIEW*

Of Semiconductor Devices, Fabrication Techniques and Processes, and Circuits and Applications

Compiled by SIDNEY MARSHALL

The abstracts appearing in this issue cover the inventions relevant to semiconductors from Aug. 4, 1959 to Aug. 25, 1959. In subsequent issues, patents issued from Aug. 25, 1959 to date will be presented inasimilar manner. After bringing these abstracts up to date, PATENT REVIEW will appear periodically, the treatment given to each item being more detailed.

AUGUST 4, 1959

2,898,407 Ignition Systems—R. L. Jaeschke. Assignee: Eaton Mfg. Co. A transistorized automotive ignition system.

2,898,407 Electronic Telephone System—G. C. Foster. Assignee: General Dynamics Corp. A transistorized automatic telephone switching system.

2,898,411 Gain Control Circuit For Semiconductor Amplifiers—W. F. Chow. Assignee: General Electric Co. An automatic gain control circuit.

2,898,454 Five Zone Composite Transistor With Common Zone Grounded To Prevent Interaction—B. D. Loughlin. Assignee: Hazeltine Research Inc. A system employing a multiple unit junction transistor, sections of which can operate independently of each other, and which are employed in at least two different circuits.

2,898,462 Demodulator—J. C. Karlson. Assignee: Bendix Aviation Corp. A discriminator circuit employing saturable reactor elements with reset windings having a transistorized operating-voltage control circuit.

2,898,474 Semiconductor Device Encapsulation—R. F. Rutz. Assignee: IBM. High current capacity device having low associated capacity is encapsulated in a translucent body of mesistylene.

2,898,476 Transistor Control Apparatus—J. R. Jensen. Assignee: Minneapolis-Honeywell Regulator Co. A system in which transistor switching action is used to control a large-power output circuit.

2,898,477 Piezoelectric Field Effect Semiconductor Device—D. H. Hoesterey. Assignee: BTL. A piezoelectric element is used to control the operation of a semiconductor device which is constructed in intimate contact therewith, said control being effected in response to a mechanical signal input.

2,898,478 Reduction of Multivibrator Recovery Time—G. L. Haugen. Assignee: Bendix Aviation Corp. A monostable transistor multivibrator having a short recovery time.

2,898,479 Clock Pulse Circuit For Transistor Flip-Flop—M. R. McElroy. Assignee: Huges Aircraft Co. A system which introduces a clock pulse into a common emitter circuit in such a way that its effect upon the flip flop is determined by the input conditions.

2,898,481 Electric Circuit Arrangement—H. A. Gahwiler. Assignee: Contraves A. G. (Switzerland). A transistor controlled RC discharge circuit having a linear discharge characteristic.

2,898,515 Thyraton Control Circuit—J. Rywak. Assignee: Northern Electric Co. Ltd. (Canada). A transistor control circuit for a two grid thyratron.

2,898,521 Electric Circuit Component—C. J. Creveling. Assignee: USA Dept. of the Navy. A printed electrical circuit component on which the individual electrical elements thereof are mounted so that their leads are attached only at the edges of the component.

2,898,522 Circuit Package—C. Hamden. Assignee: IBM. A circuit package wherein different functional characteristics may be obtained by appropriate switching of associated miniature modules.

2,898,526 Trigger Circuit For Use In Time Division Multiplex Systems—R. B. Trousdale. Assignee: General Dynamics Corp. A trigger circuit which has sufficient power output to maintain a relay operative during successive time position frames.

2,898,528 Silicon Semiconductor Device—H. Patalong. Assignee: Siemens Schuckertwerke. A. G. (Germany). A silicon device having contact electrodes made of a gold-antimony alloy containing between 0.2% to 5.0% antimony.

2,898,556 Oscillator—J. Matarese. Assignee: Sylvania Electric Products Inc. An oscillator circuit employing both an electroluminescent device and a photoconductor in a configuration whereby the interaction between the two produces an oscillatory effect.

2,898,557 Transistorized Voltage Controlled Oscillator—R. K. Dahlin. Assignee: North American Aviation Inc. A temperature compensated, stable frequency, voltage controlled time base circuit.

2,898,579 Magnetic System—T. H. Moore. Assignee: RCA. A magnetic shift register.

AUGUST 11, 1959

2,898,668 Manufacturer of Semiconductor Devices—R. D. Knott, M. R. Young. Assignee: The General Electric Co. Ltd. In a bead electrode device, means molding the bead material around end of a lead wire prior to effecting contact with the semiconductor body.

2,899,050 Radiation-proof Package Crystal Diodes—R. B. Collins, Jr. Assignee: Microwave Associates, Inc. shipping or storing package for prevent damage to semiconductor devices as result of exposure to r-f fields.

2,899,343 Junction Transistors and Methods for Making Them—H. Statz. Assignee: None. A narrow base junct semiconductor device wherein an impurity gradient is created in the base region, said gradient varying as the hyperbolic sine of the distance from emitter.

2,899,344 Fabrication of Semiconductor Devices Having Stable Surface Characteristics—M. M. Atalla, E. J. Scheibner, a E. Tannenbaum. Assignee: Bell Telephone Labs. A method of producing surface oxide films which induce desired conductivity type surface regions in semiconductor devices.

2,899,372 Method of Manufacturing Photoconductive and Rectifying Element J. M. Hanlet. Assignee: Centre d'Etud et de Developments de l'Electroniq CEDEL (France). A method of prepari conductive base plates for the devic described whereby a crystalline layer semiconductor is formed on said ba plate by cathodic projection from layer of pure metal.

2,899,547 Paging Communication Syst —R. P. Crow and R. R. Yost Jr. Assignee: Motorola, Inc. A miniature portable receiver for use in a narrow ba frequency modulation paging commun cation system.

2,899,569 Diode Circuits—R. J. Kirch Assignee: Bell Telephone Labs. Transmission and terminal impedance circuits a described which employ p-n juncti diodes operated in and near the consta voltage region of their reverse condu tion characteristic.

2,899,570 Switching Circuit—J. D. Johannesen, P. B. Myers, J. E. Schwenker. Assignee: Bell Telephone Labs. A high spe transistor gating circuit for use in info mation handling systems.

2,899,571 Switching Circuit—P. B. Mye Assignee: Bell Telephone Labs. A tra sistor controlled magnetic core gating c cuit wherein the low impedance state c

*Source: Official Gazette of the U. S. Patent Office and Specifications and Drawings of Patents Issued by the U. S. Patent Office.

e maintained continuously by a pulsed r a-c drive applied to the magnetic core.

899,572 Three Phase Power Supply—C. /. Skelton, I. Donnell, W. F. Donnell. ssignee: Texas Instruments Inc. A three hase, 400 cycle output is derived from a requency divider network supplied by a 300 cycle crystal oscillator generated gnal fed through a pulse former circuit.

899,606 Transistor Controlled Gaseous ndicator Circuits—W. J. Hicks. Assignee: Iinneapolis-Honeywell Regulator Co. A ransistor switch for a gaseous indicator ube circuit.

899,610 Electrode System Comprising rystal Diodes or Transistors—J. J. van mstel. Assignee: North American Philips o. Inc. Heat dissipating electrode systems or semiconductor devices.

899,642 Transistor Test Set—L. W. Husey. Assignee: Bell Telephone Labs. A ortable test set for indicating collector urrent with the emitter circuit open, nd current amplification factor.

899,646 High frequency Negative Resistnce Device—W. T. Read, Jr. Assignee: ell Telephone Labs. A device having neative dynamic resistance at frequencies f the order of hundreds of megacycles.

899,648 Transistor Oscillator for Vibrato urposes—M. B. Gregory. Assignee: The aldwin Piano Co. A frequency modulaon system employing an audio oscillaor and a subaudio oscillator which genrates the vibrato signal.

899,652 High Frequency Negative Resistnce Device—W. T. Read Jr. Assignee: ell Telephone Labs. In a semiconductor evice, means for localizing the field eneration of charge carriers in the space harge region.

899,659 Photocells—O. T. McIlvaine. ssignee: None. Means for producing ultiple assembly photocells.

UGUST 18, 1959

899,952 Electrical Fuel Injection Control evice for Internal Combustion Engines -R. Zechnall and K. Paule. Assignee: obert Bosch G. M. B. H. (Germany). device for controlling the amount of uel injected each cycle in proportion o the air drawn into the engine.

900,215 Transistor Record Driver — S. choen. Assignee: The National Cash egister Co. In a magnetic tape system, record driver circuit in which a pair f transistors are operated as ON-OFF ype switches.

900,280 Formation of Layers of Photoonductive Materials—H. G. Lubszynski nd J. Wardley. Assignee: Electric and usical Industries Limited, (England). An vaporation technique for forming photoonductive layers on a support.

900,286 Method of Manufacturing Semionductive Bodies—B. Goldstein. Assignee: CA. A method for introducing rectifying arriers in semiconductive materials hich contain a volatile nonmetallic eleent.

900,287 Method of Processing Semiconuctor Devices—G. M. Bestler and T. W. Iiner. Assignee: Minneapolis-Honeywell egulator Co. A method for producing lloyed junction devices with ohmic concts.

2,900,456 Direct Coupled Feedback Transistor Amplifier Circuits. J. J. Davidson. Assignee: RCA. A high dynamic input impedance amplifier circuit wherein variation of the operating points of the transistors included in the circuit is minimized.

2,900,506 Phase Detector—L. A. Whetter. Assignee: Sperry Rand Corp. A phase detector circuit which produces a d. c. output that changes polarity in response to phase reversals in the a-c input.

2,900,507 Sampling Circuit—S. C. Rogers. Assignee: Bell Telephone Labs. An arrangement for reducing the effects upon storage devices, of open circuit leakage through transistor switches in interconnected sampling circuits.

2,900,508 Discriminator—R. M. Tillman. Assignee: Burroughs Corp. A solid state pulse averaging frequency discriminator.

2,900,522 Solid State Network—C. S. Reis. Assignee: Hewlett Packard Co. In a solid state network suitable for switching, counting, storage, etc., and containing electroluminescent devices and photoconductive devices, light-coupling therein controls the operation of the system.

2,900,530 Transistor Protection Circuitry—R. W. Rowland. Assignee: Vitro Corp of America. A current limiting protective circuit for a transistor.

2,900,531 Field-Effect Transistor—J. T. Wallmark. Assignee: RCA. A filamentary bipolar germanium transistor with means for controlling the injection and flow therethrough of minority current carriers.

2,900,532 Compensating Circuit—G. H. Barnes. Assignee: Burroughs Corp. A wow and flutter compensating circuit for a subcarrier discriminator of the pulse averaging type.

2,900,533 Multiple Delay Line—R. E. Howes. Assignee: The National Cash Register Co. In a delay line, means for causing a pulse to be reflected back and forth between the ends of the line prior to being sensed at the output.

2,900,582 Transistor Test Set—J. L. Moll. Assignee: Bell Telephone Labs. Apparatus for determining the large signal alpha cut off frequency of transistors.

2,900,584 Transistor Method and Product—V. E. Bottom. Assignee: Motorola, Inc. Method for fabricating and alloyed junction transistor.

2,900,606 Transistor Multivibrator—A. H. Faulkner. Assignee: General Telephone Laboratories, Inc. A multivibrator with provision for independent control of both cycle period and pulse width ratio per cycle.

2,900,608 Modulating Circuits—J. L. Carroll, J. Ewels. Assignees: Electric and Musical Industries Limited (England). A signal modulator arrangement employing a crystal controlled oscillator.

AUGUST 25, 1959

2,900,701 Semiconductor Devices and Methods—D. I. Coggins. Assignee: Sylvalnia Electric Products Inc. Means for producing hermetically sealed semiconductor diodes including introduction of a dessicant within the structure to reduce the adverse affects of trapped moisture.

2,900,702 Method of Treating Silicon Surfaces—R. S. Ohl. Assignee: Bell Telephone Labs. In a method of treating silicon, methyl alcohol is applied to a silicon surface as a final stabilization step.

2,901,325 Method of Preparing Silicon—H. C. Theuerer. Assignee: Bell Telephone Labs. A traveling molten zone technique which includes provisions for removing boron impurities from silicon.

2,901,342 Purification of Indium—W. J. Siemons. Assignee: E. I. DuPont de Nemours and Co. A means for the oxidation and removal of zinc impurities from indium.

2,901,554 Semiconductor Device and Apparatus—I. A. Lesk. Assignee: General Electric Co. A semiconductor device providing a method for changing the current gain in response to the applied voltage, without changing the operating point of said device.

2,901,556 Semi-Conductor Amplifiers—R. Chapman, L. E. Robinson. Assignee: International Standard Electric Corp. A multistage crystal triode amplifier for use in a hearing aid.

2,901,558 Transistor Amplifier Circuits—R. R. Webster. Assignee: Texas Instruments Inc. A means for neutralizing the effects of interelectrode capacities in transistor amplifier devices.

2,901,612 Phase Shift Detector—L. E. Dwork, C. Huang. Assignee: Sylvania Electric Products Inc. A balanced phase discriminating circuit employing two opposite type junction transistors, said circuit being suitable for use as a discriminator in an f-m receiver.

2,901,638 Transistor Switching Circuit—C. Huang. Assignee: Sylvania Electric Products Inc. A switching system applicable to computers including a bistable multiple-emitter transistor circuit.

2,901,639 Semi-Conductor Multivibrator Circuit—H. J. Woll. Assignee: RCA. A monostable multivibrator circuit which employs a pair of intercoupled opposite-conductivity-type transistors and a timing capacitor which is rapidly discharged through one of the transistors to achieve a high ratio of charge to discharge time; which may be used as a frequency divider for counter applications.

2,901,640 Transistor Gates—L. Steinman. Assignee: Litton Industries, Inc. A triple input single transistor gate for combining three bilevel input signals to form a single bilevel output signal.

2,901,641 Three-State Electronic Circuit—E. L. Wolf. Assignee: General Dynamics Corp. A three state circuit which functions as a scale of three counter.

2,901,669 Daytime Off Solar Cell Flasher Circuit—J. J. Coleman. Assignee: Servel, Inc. A lamp flasher, including solar cells, which in daylight biases the transistors of the flasher circuit to a nonconducting state.

2,902,660 Electric Modulating Devices—E. Weisshaar. Assignee: Siemens-Scheickertwerke A. G. The Hall effect in InAs or InSb is employed to produce a modulator circuit.

(To be Continued)

SEMICONDUCTOR & SOLID-STATE BIBLIOGRAPHY

TITLE	PUBLICATION	CONDENSED SUMMARY	AUTHORS
The Theory of Impurity Conduction	Advances in Physics April 1961	Among the topics discussed are: definition, model, impurity wave functions, observations of impurity conduction, methods of calculating electrical conductivity at low concentrations, and the transition to a metallic form of conductivity.	N. F. Mott W. D. Tivose
Esaki Diodes	Bell Labs Record April 1961	Basic principles and applications of the Esaki diode.	G. C. Dacey
The Hall Effect and Resistivity of Tellurium	Can Jl of Physics April 1961	The Hall effect and resistivity of seven crystalline samples of highly purified tellurium were investigated over the temperature range —190°C to +350°C.	R. W. McKay W. E. Gravelle
Thermolectric Power Generation	Contemporary Phys April 1961	Discussed are: The nature of the thermoelectric effect design parameters, choice of materials, variation of performance with temperature, and practical devices.	P. J. Bateman
Tunnel Diode Square Wave Generator	Elecnc Design April 26 1961	The circuit described is capable of producing square waves of less than 1 cps to over 2 mc, with no sag and only slight overshoot.	J. L. Dalley
Transistor Switching Speed from Base Storage Charges and their Lifetimes, Part 2	Elecnc Design April 12 1961	Samples predictions are illustrated for determining rise, fall, storage, and delay time, using the stored charge and lifetime concept outlined in Part 1.	Y. C. Hwang D. S. Cleverley D. J. Monsour
Tunnel Diode Amplifier Calculator	Elecnc Design April 26 1961	A handy slide rule to reduce tedious calculations involved in the design of tunnel diode amplifier circuits.	J. R. McDermott
Transistor-Tunnel Diode Combination	Elecnc Design April 26 1961	High speed switching at relatively high-voltage levels is possible using a tunnel diode transistor combination.	C. D. Todd
Practical Aspects of Low-Frequency Tunnel Diode Amplifiers	Elecnc Design April 26 1961	A discussion of gain, stability and circuit behavior for a parallel type amplifier. Factors such as bias requirements and stabilization, as well as temperature behavior, are analyzed.	E. Gottlieb
The Choice and Design of D. C. Convertors	Elecnc Engg April 1961	The design of single-and two-transformers convertors is discussed and the performances compared. Design steps are indicated and two practical designs are worked out as examples.	J. S. Bell P. G. Wright
Charge Storage Techniques for High-Speed Switching Circuits, Part II	Elecnc Equip Engr April 1961	Design of non-saturating inverter and pulse amplifier circuit is discussed. Back-clamping techniques are used in the designs presented to prevent saturation.	J. F. Martin F. Niertit J. Shirman
Measuring Recovery Time of Ultra-Fast Diodes	Elecnc Industries April 1961	A direct measurement of recovery time of diodes below approximately 3 nonseconds has not been practical. This indirect method gives accurate results below 1 nonsecond.	G. C. Messinger
Designing Avalanche Switching Circuits	Electronics April 7 1961	Avalanche operation is reviewed and a criterion is developed for selecting transistors with this property. Basic avalanche circuits are presented and factors influencing design and application are discussed.	R. P. Rufer
Complementary Transistors Simplify Modulator Design	Electronics April 14 1961	Complementary transistor modulator has carrier and signal suppression at output, gain greater than 3 db, and high linearity.	J. E. Grau B. F. Humbel
Designing Low-Current Thermoelectric Coolers	Electronics April 21 1961	Tables and design formulae are utilized in design procedure.	R. M. Jepson G. G. Messick
Transistor Production	Elecnc Technology April 1961	Description of the production processes in the manufacture of germanium-alloy transistors.	No Author
A Procedure for the Design of Transistor Bias Networks	Electro-Tech April 1961	Transistor temperature characteristics, fixed resistance biasing, effects of variability of components, biasing with a temperature-sensitive resistor, sources of error, and approximation, are discussed.	G. E. Platzer, Jr
Quantum Electrons	Electro-Tech April 1961	Topics discussed are: Planks radiation theory, the Bohr atom, the de Broglie hypothesis of wave particle duality, the Schroedinger equation, the transmission of electrons through a potential barrier, the hydrogen atom, and application to solid state physics.	G. C. Dacey
Acoustic-Mode Scattering of Holes	IBM JL R&D April 1961	Matrix elements are calculated for acoustic-mode scattering of holes in the valence band structure typified by germanium.	M. Tiersten
Photoconductive Modulation of Microwave Electric Fields	IRE Tr Ant & Prop March 1961	This paper analyzes cadmium sulfide films in terms of the physics involved and the effect upon microwave fields. Experimental procedures indicate possible application.	W. E. Bulman B. C. Potts R. B. Green
Intermodulation Distortion Meter Employing the Hall Effect	IRE Trans Audio Mar-Apr 1961	Both the circuitry employed and the theory of operation are discussed. Measurement of I.D. at any frequency on a point-by-point basis within the range of 400 to 20,000 cps is feasible.	A. C. Todd J. N. VanScoyoc R. P. Schuck
Third-Order Distortion and Cross Modulation in a Grounded Emitter Transistor Amplifier	IRE Trans Audio Mar-Apr 1961	To reduce cross modulation in a transistor r-f stage, two possiblilities are described for correcting the distortions with a fixed or controlled working point, using a predistortion or push-pull modulation.	H. Lotsch
Thermistors, their Theory, Manufacture and Application	IRE Tr Comp Parts March 1961	This paper, in a broad survey of the subject, describes the theory, develops expressions governing their parameters, outlines methods of manufacture and describes applications.	R. W. A. Scarr R. A. Setteringto
A Controlled-Temperature Device for Transistor Tests	IRE Tr Educ March 1961	A laboratory device for operating transistors at selected known temperatures in the 15° to 95° C range is described. The unit is simple, rugged, and easily constructed.	E. F. King F. L. Walker
Parametric Amplifier Using A Silver Bonded Diode	IRE Tr Elecnc Dvcs March 1961	Description of a bonded type diode composed of a silver-gallium wishker and an n-type germanium. The cutoff frequency is higher than 150 kMC.	S. Kita T. Okajima C. Chung

TITLE	PUBLICATION	CONDENSED SUMMARY	AUTHORS
High Linear Amplification with Transistors	IRE Tr Elecnc Dvcs March 1961	Experimental results to demonstrate high linear amplification with high frequency diffused base transistors in the common base configuration are presented. Also demonstrated are the causes for the above. Expressions in optimum bias voltages and currents are derived, and a general method for analytically treating nonlinearity in all transistor configurations is presented.	N. C. Chasek
Simulating Parametric Amplifiers	IRE Tr Elecnc Dvcs March 1961	The problems of producing a general simulator model of a parametric amplifier are discussed. A brief discussion of the theory behind parametric amplification is followed by proposals for three models.	W. T. Hatley, Jr.
The Reverse Transient Behavior of Semiconductor Junction Diodes	IRE Tr Elecnc Dvcs March 1961	The reverse transient behavior of junction diodes for a rectangular pulse of forward current, is analyzed, and the results verified experimentally.	W. H. Ko
Response of a P-N Junction to a Linearly Decreasing Current	IRE Tr Elecnc Dvcs March 1961	It is shown that the period between the reversal of current and the reversal of voltage depends exclusively on the lifetime, diffusion length, and thermal equilibrium densities of minority carriers in both regions of the junction.	M. A. Melsky W. Shockley
Charge Analysis of Transistor operation Including Delay Effects	IRE Tr Elecnc Dvcs March 1961	Defining the transit time as the ratio of the excess base charge to the collector current, the transform of the transit time is approximated. For a one-dimensional, homogeneous-base transistor, the results of this technique are in good agreement with exact calculations.	A. N. Baker W. G. May
A Unidirectional Amplifier With Esaki Diodes	IRE Tr Elecnc Dvcs March 1961	This paper describes how a Hall-Effect isolator can be combined with voltage-controlled (or short-circuit stable) negative conductances (Eskai Diodes) to produce a unidirectional amplifier.	W. J. Grubbs
Synthesis Using Tunnel Diodes and Masers	IRE Tr Cir Theory March 1961	Some procedures for active network synthesis that require the use of negative resistance are presented in this paper.	L. Weinberg
Impurity Band Conduction and the Problem of Excess Current In Tunnel Diodes	JL Appl Phys April 1961	A three dimensional theory of impurity band formation in degenerate germanium which is a modification of the other current theories is described.	T. P. Brody
Effects of Doping Additions On The Thermoelectric Properties of the Intrinsic Semiconductor $Bi_2Te_{2.1}Sc_{0.9}$	JL Appl Phys April 1961	Investigation of conductivity type determinants, and Seebeck coefficient, electrical conductivity, and thermal conductivity as a junction of impurity concentration are described.	L. C. Bennett J. R. Wiese
Determination of The Semiconductor Surface Potential Under A Metal Contact	JL Appl Phys April 1961	Semiconductor surface barrier height under a metal contact is measured by infrared absorbtion techniques.	N. J. Harrick
Surface Electrical Changes Caused By The Adsorbtion of Hydrogen and Oxygen On Silicon	JL Appl Phys April 1961	Measurements of conductance, lifetime, light induced contact potential changes, and contact potential are conducted for bombardment cleaned silicon surfaces and during absorbtion of molecular oxygen and hydrogen.	J. T. Law
Effect of Freezing Conditions On Thermoelectric Properties of $BiSbTe_3$ Crystals	JL Appl Phys April 1961	The Seebeck coefficient, resistivity and thermal conductivity are measured as a function of the freezing velocity.	G. J. Cosgrove J. P. McHugh W. A. Tiller
Current Flow Across Grain Boundaries In N-type Germanium, I	JL Appl Phys April 1961	At low temperatures the current across grain boundaries in n-type germanium is determined by carrier generation and annihilation in the space charge region.	R. K. Mueller
Current Flow Across Grain Boundaries In n-type Germanium, II	JL Appl Phys April 1961	Experimental results concerning current flow across grain boundaries in Ge bicrystals with different boundary structures and a wide range of donor content are presented.	R. K. Mueller
Operation of Tunnel Emission Devices	JL Appl Phys April 1961	Applications and limitations of tunnel emission devices are discussed and several successful devices are described.	C. A. Mead
Mobility of Radiation Induced Defects In Germanium	JL Appl Phys April 1961	The motion of radiation induced defects in germanium under the influence of a high electric field in the space charge region of a reversed biased p-n junction is discussed.	P. Baruch
Interference Method For Measuring The Thickness of Epitaxially Grown Films	JL Appl Phys April 1961 (Letter to Ed)	A method based upon differences in dielectric constant between two samples of the same semiconductor the difference being due to variations in carrier concentration.	W. G. Spitzer M. Tannenbaum
Chemical Etching of Silicon, III. A Temperature Study in the Acid System	JL Electrochem Soc April 1961	The etch rate of silicon in solutions of various compositions selected from the system, HF, HNO_3 H_2O and $HC_2H_3O_2$ has been investigated over the temperature range 0° to 50°C.	B. Schwartz H. Robbins
Use of Hall Measurements in Evaluating Polycrystalline Silicon	JL Electrochem Soc April 1961	The method does not require cutting of samples and destruction of rods. Current contacts are made to the ends of a rod with strips of metal foil. Hall contacts are made with two titanium blades which close on the rod.	P. J. Olshefski D. J. Shombert I. R. Weingarten
Preparation of High-Purity Indium Arsenide	JL Electrochem Soc April 1961	The purest indium arsenide has a carrier concentration several times the intrinsic value. Measurements have been made and conclusions reached regarding this phenomenon.	D. Effer
Preparation and Properties of Grown P-N Junctions of InSb	JL Electrochem Soc April 1961	The effects of anisotropic distribution of impurities within the crystals were observed in the electrical properties of the diodes. The lifetimes of minority carriers at high injection levels (forward bias) was observed.	H. C. Gortor A. R. Zacaroli F. J. Reid C. S. Peet
On The Control of Electroluminescent Cells by Unipolar Transistors	JL Elecncs & Control April 1961	By varying the channel conductance the supply voltage can be shifted from the unipolar to transistor to the EL cell and vice versa. An approach to the design of a control element is given with an example.	T. N. Chin
Magnetoresistance Measurements by Means of Arbitrarily Shaped Flat Samples	JL Elecncs & Control April 1961	A method of measuring magnetoresistance coefficient of cubic materials is described. The method utilizes two flat samples of arbitrary perimeter.	H. Matthews W. R. Doherty
Electrical Properties of Heavily Doped N-type Germanium	JL Phys Soc Japan April 1961	Experimental studies were made on electrical resistivity, Hall coefficient, and magnetoresistance of As-, Sb-, and (As + Sb)—doped germanium.	Y. Furukawa

TITLE	PUBLICATION	CONDENSED SUMMARY	AUTHORS
Ferromagnetic Resonance Absorption of Single-Crystal Thin Films of Nickel	JL Phys Soc Japan April 1961	By the experiment of ferromagnetic resonance absorption at room temperature, three magnetic quantities were measured at the same time: saturation magnetization, crystalline anisotropy, and the Lande' splitting factor.	M. Kuriyama H. Yamanauchi S. Hosoya
Regrowth of Germanium from Molten Indium or Lead	JL Phys Soc Japan April 1961	A single crystal of n-type germanium was alloyed with indium on its (111) plane, and the resulting regrown layer of p-type germanium was observed.	M. Tomono
Low-Temperature Electrical Breakdown in Germanium	JL Phys Soc Japan April 1961	The low-temperature electrical breakdown effect in n-type germanium which was observed by Sclar and Burstein, and Koenig and Gunther-Mohr, is discussed from the hot electron theory.	J. Yamashita
Studies on the Boundary Between the Etched and Ground Regions at Ge and Si Single Crystal Surface by X-Ray Diffraction Topography	JL Phys Soc Japan April 1961	The anamolous boundary effect similar to those found by Fukushima in quartz were studied by X-Ray diffraction topography methods in Ge and Si single crystals. Results are reasonably explained by assuming a strain gradient perpendicular to the boundary.	Z. Ishii
An Improvement to the Floating Zone Method of Growing Single Crystals	JL Scient Instrmnts April 1961	Method of keeping grown rods straight for long operating periods.	G. W. Green
Use of "Air-Bleed" when Measuring Pressure in Vacuum Processes in Which Condensable Vapours are Present	JL Scient Instrmnts April 1961	A pressure-measuring method is described which prevents condensation or liquefaction occurring in the manometer or in the line connecting it to a vacuum system.	H. Wycliffe
Solid-State Research at Low Temperatures, II. Electron Conduction in Metals and Semiconductors	Philips Tech Rev April 5, 1961	Results of experiments on aluminum, copper, iron, tantalum and some extrinsic semiconductors are analyzed.	J. Volger
Properties and Applications of Indium Antimonide	Philips Tech Rev April 5, 1961	Preparation of InSb crystals and the construction and performance of photocells based on InSb are described.	R. E. J. King B. E. Bartlett
The Rate of Attainment of Equilibrium in the Cooling of Alloys	Physica April 1961	The deviations from equilibrium which occur during cooling an alloy are calculated for a simple case. The cases of vacancy concentration, short range order of the atoms and precipation are calculated for a stepwise way of cooling and for a constant cooling rate.	M. J. Druyvestey
Cyclotron Resonance in Indium Antimonide at High Magnetic Fields	Physical Review April 1, 1961	The room temperature pulsed magnetic field infrared cyclotron resonance data of Keyes and co-workers in indium antimonide is interpreted using the k.p. perturbation technique of Kane, which is extended to include the effects of a d-c magnetic field.	B. Lax J. G. Mavroides H. J. Zeiger R. J. Keyes
Fine Structure and Magneto-Optic Effects in the Exciton Spectrum of Cadmium Sulfide	Physical Review April 1, 1961	The valence band of cadmium sulfide is split by spin-orbit and crystal field effects into three nearly degenerate bands at k-o. The magneto-optic absorption spectrum of direct excitons formed from the top valence band and the conduction band has been studied in detail.	J. J. Hopfield D. G. Thomas
Direct Current Electroluminescence at Low Voltage	Physical Review April 1, 1961	EL due to d-c excitation occurs in activated ZnS films at 2.0 volts. It is concluded that the acceleration collision theory of EL at low voltage is ruled out.	W. A. Thornton
Theory of Auger Neutralization of Ions at the Surface of a Diamond Type Semiconductor	Physical Review April 1, 1961	The two-electron Auger-type transition which occur when an ion of sufficiently large ionization energy is neutralized at the atomically clean surface of a diamond-type semiconductor are discussed.	H. D. Hagstrum
Current Noise and Distributed Traps in Cadmium Sulfide	Physical Review April 1, 1961	Photoconductivity in single crystal CdS is strongly influenced by the characteristics and energy distribution of shallow traps. In the present work a more extensive study using current noise measurements, is reported.	J. J. Brofly
Cyclotron Resonance in Germanium	Physical Review April 1, 1961	A comparison is made of the cyclotron resonance theory, and the experiments of Fletcher, Yaeger and Merritt. Values of the effective mass constants which best fit the data are found.	R. R. Goodman
Photothermal Effect in Semiconductors	Physical Review April 15, 1961	Formulation of the theory governing the photothermal effect, and the case of small temperature elevation in an infinite slab is worked out in detail.	W. W. Gartner
Galvanomagnetic Effects in N-Ge in the Impurity Conduction Range	Physical Review April 15, 1961	The magnitude of and the crystalline anisotropy of the magnetoresistance are interpreted in terms of the changes in the donor wave functions which are produced by the magnetic field.	R. J. Sladek R. W. Keyes
Lattice Thermal Conductivity of Germanium-Silicon Alloy Single Crystals at Low Temperatures	Physical Review April 15, 1961	Thermal conductivity measurements are reported for five single crystal Ge-Si specimens containing 0-7.56 at. % Si.	A. M. Toxen
Infrared Cyclotron Resonance in InSb	Physical Review April 15, 1961	Far-infrared cyclotron absorption in n-type InSb has been measured to determine the variation of the conduction electron effective mass with magnetic field.	E. D. Palik G. S. Picus S. Teitler F. F. Wallis
Three-Layer Negative Resistance and Inductive Semiconductor Diodes	Proc IRE April 1961	This paper shows that in transistor-like three-layer structures with the base either open-circuited or directly shorted to the emitter region, negative resistances are observed when any two of several effects listed occur simultaneously.	W. W. Gartner M. Schuller
Tunnel Diode Microwave Oscillators	Proc IRE April 1961	Several experimental tunnel diode r-f oscillators which operate at frequencies from 610 to 8350 mc are described. Problems related to oscillation frequency, power output, and wave shape are treated analytically.	F. Sterzer D. E. Nelson
A Noise Investigation of Tunnel Diode Microwave Amplifiers	Proc IRE April 1961	An analysis and derivation of the noise figure of a tunnel-diode microwave amplifier are presented.	A. Yariv J. S. Cook
Transistor Internal Parameters for Small-Signal Representation	Proc IRE April 1961	A joint IRE-AIEE Task Group report on "Transistor Internal Parameters." Three objectives covered in this article are: 1) formulations of a small-signal equivalent representation of a transistor, 2) symbol representation of pertinent parameters, and 3) relationship between equivalent circuit representation and simplified representations commonly employed in circuit design and analysis.	R. L. Pritchard J. B. Angell R. B. Adler J. M. Early W. M. Webster

TITLE	PUBLICATION	CONDENSED SUMMARY	AUTHORS
hermal Behavior of Silicon Car-ide Valve Blocks	Pwr App & Syst (AIEE) April 1961	A mathematical analysis of the transient thermal behavior of these lightning-arrestor valve blocks.	N. E. Bolen
leasurement of Electrical Resis-vity of Bulk Metals	Rev Scient Instmnts April 1961	Method of measuring the electrical resistivity of metals by a-c induction methods, in which the specimen is in bulk form, and no direct contact to it is required.	J. E. Zimmerman
ffect of Thermal Treatment of ilicon On Minority Carrier Life-me	Sov Phys Solid State March 1961	The formation of recombination centers in aluminum is determined by the annealing process as well as by high temperature.	V. A. Atsarkin E. Z. Mazel
iffusion of Antimony In German-im Alloyed With Aluminum	Sov Phys Solid State March 1961	The diffusion coefficient of antimony increases with greater concentration of aluminum in the temperature range 650°C to 930°C.	I. P. Akimchenko L. S. Milevskii
ow Inertia Germanium Diodes	Sov Phys Solid State March 1961	Low inertia photo diodes having time constants in the order of 2×10^{8} sec have been developed and tested.	S. M. R. Yvkin R. B. Konopleva L. V. Maslova
he Conductivity of P-N Junc-ons In The Reverse Direction	Sov Phys Solid State March 1961	The absence of a saturation of the reverse current in Ge, Si, and Se p-n junctions is thought to be due to a decrease of the activation energy which occurs in the junction under the influence of the field.	V. I. Fistul' O. B. Orzhevskii
Mechanism For The Intro-uction of Recombination Centers n Germanium and Silicon During ow Temperature Quenching.	Sov Phys Solid State March 1961	The mechanism mentioned depends upon the displacement of dislocations as a result of thermal shocks and the separation of said dislocations from their impurity atmospheres.	L. S. M. Levskii
ffect of Electric Field on The emperature of Electrons, Elec-rical Conductivity, and Thermi-nic Emission of Semiconductors	Sov Phys Solid State March 1961	The distribution function of electrons in atomic semiconductors in the presence of an electric field is developed.	I. M. Dykman P. M. Tomchuk
igh Speed Logic Using Low-Cost lesa Transistors	Semiconductor Prods April 1961	This article discusses the use of the 2N1301 mesa switching transistor in digital logic circuits. Two systems are described, RCTL and RTL, and performance data for both systems are presented.	D. Gipp R. D. Lohman R. R. Painter B. Zuk
bservations on Semiconductor evice Reliability	Semiconductor Prods April 1961	Highlights of papers, presented at the Conference on the Reliability of Semiconductor Devices held in N. Y. C. on Jan. 12, and 13, 1961, with reference to causes of device degradation, detection of causes, and methods of improving device reliability.	H. J. Sullivan L. L. Scheiner
Transistorized Count Rate Meter	Semiconductor Prods April 1961	Meter, suitable for general laboratory or field use with scintillation detectors or Geiger tubes, is described.	P. Goldstein
he Silicon Transistor, A High-ower N-P-N-P Triode Switch	Semiconductor Prods April 1961	Design considerations and performance are discussed. Currents up to 50 amperes at room temperature and 20 amperes in ambient temperatures up to 150°C can be switched, with gate triggering currents of approximately 10 ma.	F. S. Stein E. W. Torok
acuum Float Zone Refining of ilicon	Semiconductor Prods April 1961	Description of ultra-high vacuum technology, design and operation of process. Also discusses purity, diameter control and doping.	F. Bourassa
Low-Drift Direct-Coupled ransistor Amplifier for High emperature Applications	Semiconductor Prods April 1961	A direct-coupled transistor amplifier circuit which is suitable for high temperature applications is described. Amplifier exhibited no drift over the temperature range from 25°C to +125°C.	J. W. Halligan
Graphical Design Procedure for ransistor Resistor Logic Stages	Semiconductor Prods April 1961	Approach presented in this paper is a graphical d-c design that allows transient optimization through bench testing to be performed on logically correct circuits.	T. L. Francis
ntimony, Bismuth, Gallium, In-ium, Selenium, and Tellurium	US Govt Res Repts April 1961 OTS $0.10 OTS SB-438	A sixteen page bibliography covering the period 1950 to October 1960.	
ermanium and Silicon	US Govt Res Repts April 1961 OTS $0.10 OTS SB-437	A 21 page bibliography covering the period 1950 to September 1960.	
New Semiconductor Micro-Wave lodulator	US Govt Res Repts April 1961 LC $4.80 PB153001	A semiconductor rod placed in a waveguide acts as a microwave amplitude modulator by absorbing microwave energy when its conductivity is varied in a controlled manner.	H. Jacobs F. A. Brand
olar Cell Measurement Standard-zation	US Govt Res Repts April 1961 LC $13.80 PB153645	A symposium report covering solar call standards, instrumentation and applications, etc.	No Author
ndium Antimonide For Semicon-uctor Device Feasibility Studies	US Govt Res Repts April 1961 OTS $1.75 PB171406	A report on some material fabrication methods and on the electrical and physical characteristics of said materials.	F. J. Reid
he Study Of A Class of Inter-netallic Compounds. The Chal-opyrites	US Govt Res Repts April 1961 LC $10.80 PB150323	Hardness, crystallographic structure and resistivity of these materials were investigated and certain ones were found to be true intermetallic semiconductors.	S. Zalar I. Cadoff
olid State Division Annual Prog-ess Report For Period Ending 31 ugust 1960	US Govt Res Repts April 1961 OTS $2.50 ORNL-3017	An Oak Ridge National Laboratory report.	D. S. Billington J. H. Grawford Jr.
unnel Diode Applications To ogic And Pulse Circuits.	US Govt Res Repts April 1961 OTS $1.00 SCTM-375-60-72	A report from the Sandia Corp.	I. W. Janney
volution of the Horizontal Crystal	Western Elec Engr April 1961	Description and discussion of early machines, following which a discussion of the development of the new machine is given.	W. D. Eisenhower
ransfer Dies for Transistor Com-onents	Western Elec Engr April 1961	Precision transfer components are produced, and a new use of an old tooling concept is described.	F. A. Haggerty E. A. Kromer D. V. Oltman

CHARACTERISTICS CHARTS OF NEW DIODES and RECTIFIERS

MANUFACTURERS

AEG— Allgemeine Elekticitats-Gesellschaft
ASC— American Semiconductor Corp.
AMP— Amperex Electronic Corp.
AEI— Associated Electrical Industries, Ltd.
ATLB— Associated Transistors, Ltd.
BEN— Bendix Corp.
BER— Berkshire Corp.
BOM— Bomac Labs
BRA— Bradley Semiconductor Corp.
BRI— Britton Electronics Corp.
CBS— CBS Electronics
CDC— Continental Device Corp.
CDLF— Compagnie des Lampes
COD— Computer Diode Corp.
COL— Columbus Electronics Corp.
CON— Controls Co., of America
CTP— Clevite Transistor Products, Inc.
CSF— (Cosem) Cie Generale des Semi-Conducteurs
DEL— Delco Radio
DES— Delta Semiconductors, Inc.
DIC— Dickson Electronics Corp.
EEVB— English Electric Valve Co., Ltd.
ERI— Erie Resistor Corp.
ESP— Espey Mfg. and Electronics Corp.
FAN— Fansteel Metallurgical Corp.
FERB— Ferranti Ltd.
FSC— Fairchild Semiconductor Corp.
GAH— Gahagan, Inc.
GECB— General Electric Co., Ltd.
GE— General Electric Company, Semiconductor Div.
GELC— Canadian General Electric Co.
GIC— General Instrument Corp.
HAFO— Institutet for Halvedarforskning
HITJ— Hitachi Ltd., Mushashi Works
HUG— Hughes Products Division
HUGS— Hughes Int'l. (U.K.) Ltd.
ITC— Industro Transistor Corp.
IDC— International Diode Corp.
INRB— International Rectifier Co., Ltd.
INRC— International Rectifier Corp.
IRC— International Resistance Co.
ITT— International Tel. & Tel. Corp.
KEM— Kemtron Electron Products, Inc.
KOKJ— Kobe Kogyo Corp.
MAL— P. R. Mallory & Co., Inc.
MATJ— Matushita Electronics Corp.
MSC— MicroSemiconductor Corp.
MIC— Microwave Associates, Inc.
MISI— Mistral
MOT— Motorola, Inc
MUL— Mullard, Ltd.
NSLC— National Semiconductors, Ltd.
NAE— North American Electronics
NPC— Nucleonic Products Co., Inc.
PHI— Philco Corp. Lansdale Div., Semiconductor Operations
PHIN— Philips Gloeilampenfabrieken
PLEB— The Plessey Co.
PRI— Princeton Electronics Corp.
PSI— Pacific Semiconductors, Inc.
RADF— La Radiotechnique Div. Tubes Electroniques
RAY— Raytheon Company
RCA— Radio Corporation of America, Semiconductor Div.
RDR— Radio Development and Research Corp.
RHE— Rheem Semiconductor Corp.
HSD— Hoffman Semiconductor Division
ROSG— Dr. Ing. Rudolph Rost
SAR— Sarkes Tarzian, Inc., Rectifier Division
SCN— Semicon, Inc.
SEM— Semi-Elements Inc.
SIE— Siemens & Halske Aktiengesellschaft
SIL— Silicon Transistor Corp.
SGSI— Societa Generale Semiconduttori
SHEJ— Schindengen Elect. Mfg. Co., Ltd.
SLA— Slater Electric Inc.
SOIF— Societe Industrial de Liaisons
SOD— Solitron Devices, Inc.
SONY— Sony Corp.
SSD— Sperry Semiconductor Division
SSP— Solid State Products, Inc.
STC— Shockley Transistor Corp.
STCB— Standard Telephone & Cables, Ltd.
STCA— Standard Tel. and Cables Pty, Ltd.
SYL— Sylvania Electric Products, Inc.
SYN— Syntron Co.
TEX— Texas Research Assoc.
TFKG— Telefunken, Ltd.
TI— Texas Instruments Incorporated
TKD— Tekade
TRA— Transitron Electronic Corp.
TUN— Tung-Sol Electric, Inc.
TSC— Trans-Sil Corp.
UCI— United Components
UNI— Unitrode Transistor Prods., Corp.
USS— U. S. Semiconductor Products, Inc.
VIC— Vickers Inc.
WEC— Western Electric Co.
WESB— Westinghouse Brake and Signal Co., Ltd.
WEST— Westinghouse Electric Corp.

CHARACTERISTICS CHART of DIODES and RECTIFIERS

TYPE NO.	USE (See Code Below)	MAT	PIV	MAX. CONT. WORK. VOLT.	Min. Forward Current @ 25°C		MAX. D.C. OUTPUT CURRENT⁴ @ T (°C)		MAX. FULL LOAD VOLT. DROP⁴	Max. Rev. Current			MFR. (See code at start of charts)
					I_f	@ E_f				I_b	@ E_b	@ T	
			(volts)	(volts)	(mA)	(volts)	(amps)		(volts)	(uA)	(volts)	(°C)	
1N3147	1	S1		60	100	1.0				20	30	100	DES
1N3189	1	S1		240	750	1.0				500	200	150	DES
1N3190	1	S1		480	750	1.0				500	400	150	DES
1N3191	1	S1		720	750	1.0				500	600	150	DES
1N3294	2		800	560			100	130C		5500		130C	GE
1N3295	2		1000	700			100	130C		4500		130C	GE
1N3486	2	S1	1000	1000	400	2.0	.20	35A		2.0	1000	25A	COL
1N3487	2	S1	1200	1200	400	2.0	.20	35A		2.0	1200	25A	COL
1S40	2	S1	100		1.0	1.2				250	100	150A	KOKJ
1S41	2	S1	200		1.0	1.2				250	200	150A	KOKJ
1S42	2	S1	300		1.0	1.2				250	300	150A	KOKJ
1S43	2	S1	400		1.0	1.2				250	400	150A	KOKJ
1S44	2	S1	500		1.0	1.2				350	500	150A	KOKJ
1S45	2	S1	600		1.0	1.2				350	600	150A	KOKJ
1S46	2	S1	700		1.0	1.2				500	700	150A	KOKJ
1S47	2	S1	800		1.0	1.2				500	800	150A	KOKJ
1S77	1	Ge		60	25	1.0	.25	25		250	60	25	HITJ
1S78	1	Ge		40	50	1.0	.35	25		200	40	25	HITJ
1S79	1	Ge		20	8.0	1.0	.45	25		200	20	25	HITJ
1S83	1	Ge		80	250	.50	2.0	25		60	80	25	HITJ
1S84	1	S1		200	100	1.0	.50	25		2.0	200	25	HITJ
1S85	1	S1		20						5.0	20	25	HITJ
1S146	2	S1	100		1.0	1.2				250	100	100A	KOKJ
1S147	2	S1	200		1.0	1.2				250	200	100A	KOKJ
1S148	2	S1	300		1.0	1.2				250	300	100A	KOKJ
1S149	2	S1	400		1.0	1.2				250	400	100A	KOKJ
1S150	2	S1	500		1.0	1.2				250	500	100A	KOKJ
1S205	1	S1	50	50	400	1.0	.100	125A		.10	50	25	SGSI
1S210	1	S1	100	100	400	1.0	.100	125A		.10	100	25	SGSI

CHARACTERISTICS CHART of DIODES and RECTIFIERS

TYPE NO.	USE (See Code Below)	MAT	PIV	MAX. CONT. WORK. VOLT.	Min. Forward Current @ 25°C		MAX. D.C. OUTPUT CURRENT⁴ @ T (°C)		MAX. FULL LOAD VOLT. DROP⁴	Max. Rev. Current			MFR. (See code at start of charts)
					I_f	@ E_f				I_b	@ E_b	@ T	
			(volts)	(volts)	(mA)	(volts)	(amps)		(volts)	(uA)	(volts)	(°C)	
1[illegible]230	1	[illegible]	300	300	400	1.0	.100	125A		.10	300	25	SGSI
1[illegible]240	1	[illegible]	400	400	400	1.0	.200	25A		.10	400	25	SGSI
1[illegible]250	1	[illegible]	500	500	400	1.0	.200	25A		.10	500	25	SGSI
1[illegible]1114	2	[illegible]	50	50			1.5	85	.65	400	50	150	SGSI
3M	2		600	420	3000	1.0	3.0	25	1.0	5.0	600	130	INRJ
6A	2		600	420	6000	1.0	6.0	25	1.0	10	600	130	INRJ
10ST		S1		100			.50	100	1.5	2000	100	25	SOD
20ST		S1		200			.50	100	1.5	2000	200	25	SOD
25H	2		600	420	25K	1.0	25	25	1.0	10	600	165	INRJ
30ST		S1		300			.50	100	1.5	2000	300	25	SOD
40ST		S1		400			.50	100	1.5	2000	400	25	SOD
45L	2		800	560	45K	1.0	45	25	1.0	40	800	175	INRJ
70U	2		500	350	70K	1.0	70	25	1.0	55	500	175	INRJ
500ST		S1		400			.50	100	1.5	2000	400	25	SOD
BAY17	1	S1	15		20	1.0							INTG
BY103	2	S1	750				.60	50A					INTG
BYY31	2	S1	100				.60	50A					INTG
BYY32	2	S1	200				.60	50A					INTG
BYY33	2	S1	300				.60	50A					INTG
BYY34	2	S1	400				.60	50A					INTG
BYY35	2	S1	500				.60	50A					INTG
BYY36	2	S1	600				.60	50A					INTG
BYY37	2	S1	700				.60	50A					INTG
[illegible]	2		16K	11200	300	30	.30	25	30	25	16K	25	INRJ
[illegible]	5	S1	25	25			7.0	40A	1.2	22.5ma		100A	SHEJ
[illegible]	5	S1	50	50			7.0	40A	1.2	19ma		100A	SHEJ
[illegible]	5	S1	100	100			7.0	40A	1.2	12.5ma		100A	SHEJ
[illegible]	5	S1	150	150			7.0	40A	1.2	6500		100A	SHEJ
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]			[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]

NO.	Code Below		(volts)	VOLT. (volts)	I_f (mA)	@ E_f (volts)	(amps)		VOLT. DROP[4] (volts)	(uA)	(volts)	(°C)	at start of charts
C3B40	5	S1	400	400			7.0	40A	1.2	4000		100A	SHEJ
CID205	1	Ge		100	10	.50				50	80	25	CTP
CR80.021	5	S1	25				80	100J	2.5				AEIL
CR80.051	5	S1	50				80	100J	2.5				AEIL
CR80.071	5	S1	75				80	100J	2.5				AEIL
CR80.101	5	S1	100				80	100J	2.5				AEIL
CR80.151	5	S1	150				80	100J	2.5				AEIL
CR80.201	5	S1	200				80	100J	2.5				AEIL
CR80.251	5	S1	250				80	100J	2.5				AEIL
CR80.301	5	S1	300				80	100J	2.5				AEIL
CR100.021	5	S1	25				100	100J	2.0				AEIL
CR100.051	5	S1	50				100	100J	2.0				AEIL
CR100.071	5	S1	75				100	100J	2.0				AEIL
CR100.101	5	S1	100				100	100J	2.0				AEIL
CR100.151	5	S1	150				100	100J	2.0				AEIL
CR100.201	5	S1	200				100	100J	2.0				AEIL
CR100.251	5	S1	250				100	100J	2.0				AEIL
CR100.301	5	S1	300				100	100J	2.0				AEIL
CR101	2	S1	1200	1200			.825	60A	1.2	300	1200	125A	RCA
CR102	2	S1	2000	2000			.825	60A	2.4	300	2000	125A	RCA
CR103	2	S1	3000	3000			.715	60A	3.0	300	3000	125A	RCA
CR104	2	S1	4000	4000			.605	60A	4.2	300	4000	125A	RCA
CR105	2	S1	5000	5000			.605	60A	4.8	300	5000	125A	RCA
CR106	2	S1	6000	6000			.550	60A	6.0	300	6000	125A	RCA
CR107	2	S1	7000	7000			.550	60A	7.2	300	7000	125A	RCA
CR108	2	S1	8000	8000			.550	60A	7.8	300	8000	125A	RCA
CR109	2	S1	9000	9000			.550	60A	9.0	300	9000	125A	RCA
CR110	2	S1	10K	10K			.550	60A	9.6	300	10K	125A	RCA
DRS1	1	S1	300		400	1.0				5.0	175	150	DES
DRS2	1	S1	1000		400	1.0				5.0	175	150	DES
E	2		400	280	300	1.3	.30	25	1.3	500	400	100	INRJ
G50E	2	Ge	200	200			30	40A					SHEJ
HR12	5	S1		200						100	200	25	HITJ
HR13	5	S1		300						100	300	25	HITJ
HR24	5	S1		400						100	400	25	HITJ
HR25	5	S1		500						100	500	25	HITJ
HS1020	1	S1	200	200	200	1.0	.165	25A		.02	200	25A	HUGS
HVC1	2	S1	1000	1000	400	2.0	.15	35A		5.0	1000	25A	COL
HVC2	2	S1	2000	2000	400	4.0	.15	35A		5.0	2000	25A	COL
HVC3	2	S1	3000	3000	400	4.0	.15	35A		5.0	3000	25A	COL
HVC4	2	S1	4000	4000	400	6.0	.15	35A		5.0	4000	25A	COL
HVC6	2	S1	6000	6000	400	8.0	.15	35A		5.0	6000	25A	COL
HVC8	2	S1	8000	8000	400	10	.10	35A		5.0	8000	25A	COL
HVC10	2	S1	10K	10K	400	12	.10	35A		5.0	10K	25A	COL
HVC12	2	S1	12K	12K	400	14	.10	35A		5.0	12K	25A	COL
HVC14	2	S1	14K	14K	400	16	.10	35A		5.0	14K	25A	COL
HVC16	2	S1	16K	16K	400	18	.10	35A		5.0	16K	25A	COL
HVC18	2	S1	18K	18K	400	20	.10	35A		5.0	18K	25A	COL
HVC20	2	S1	20K	20K	400	24	.10	35A		5.0	20K	25A	COL
K	2		1200	840	100	6.0	.10	25	6.0	25	1200	25	INRJ
LHV1000	1	S1	1000		.100	5.0	.20	100		10	1000	25	ITT
LHV1500	1	S1	1500		.100	5.0	.20	100		10	1500	25	ITT
LHV2000	1	S1	2000		.100	9.0	.20	100		10	2000	25	ITT
LHV3000	1	S1	3000		.100	12	.15	100		10	3000	25	ITT
LHV5000	1	S1	5000		.100	18	.10	100		10	5000	25	ITT
OMC100	1	Ge	75	60	600	1.0	.08	25		100	50	25	OHM
OMC282	1	Ge	25	20	8.0	1.0	.02	25		15	10	25	OHM
OMC287	1	Ge	15	12	200	1.0	.08	25		15	10	25	OHM
OMC550	1	Ge	30	25	500	1.0	.08	25		100	10	25	OHM
OMC560	1	Ge	25	20	600	1.0	.08	25		200	10	25	OHM
S	2		600	420	300	1.5	.30	25	1.5	25	600	25	INRJ
S2A10	1	S1	100	100			1.5	40A	1.1	500	100	25A	SHEJ
S2A20	1	S1	200	200			1.5	40A	1.1	500	200	25A	SHEJ
S2A30	1	S1	300	300			1.5	40A	1.1	500	300	25A	SHEJ
S2A40	1	S1	400	400			1.5	40A	1.1	500	400	25A	SHEJ
S2A50	1	S1	500	500			1.5	40A	1.1	500	500	25A	SHEJ
S2A60	1	S1	600	600			1.5	40A	1.1	500	600	25A	SHEJ
S2A80	1	S1	800	800			1.5	40A	1.1	500	800	25A	SHEJ
S2A100	1	S1	1000	1000			1.5	40A	1.1	500	1000	25A	SHEJ
S5B10	2	S1	100	100			20	40A	1.1	2500	100	25A	SHEJ
S5B20	2	S1	200	200			20	40A	1.1	2500	200	25A	SHEJ
S5B30	2	S1	300	300			20	40A	1.1	2500	300	25A	SHEJ
S5B40	2	S1	400	400			20	40A	1.1	2500	400	25A	SHEJ
S5B50	2	S1	500	500			20	40A	1.1	2500	400	25A	SHEJ
S5B60	2	S1	600	600			20	40A	1.1	2500	500	25A	SHEJ

NO.	Code Below		(volts)	VOLT. (volts)	I_f (mA)	@ E_f (volts)	(amps)		VOLT. DROP[4] (volts)	(uA)	(volts)	(°C)	at start of charts
S5B80	2	S1	800	800			20	40A	1.1	2500	800	25A	SHEJ
S5B100	2	S1	1000	1000			20	40A	1.1	2500	1000	25A	SHEJ
S8B10	2	S1	100	100			50	40A	1.1	6300	100	25A	SHEJ
S8B20	2	S1	200	200			50	40A	1.1	6300	200	25A	SHEJ
S8B30	2	S1	300	300			50	40A	1.1	6300	300	25A	SHEJ
S8B40	2	S1	400	400			50	40A	1.1	6300	400	25A	SHEJ
S8B50	2	S1	500	500			50	40A	1.1	6300	500	25A	SHEJ
S8B60	2	S1	600	600			50	40A	1.1	6300	600	25A	SHEJ
S8B80	2	S1	800	800			50	40A	1.1	6300	800	25A	SHEJ
S8B100	2	S1	1000	1000			50	40A	1.1	6300	1000	25A	SHEJ
S16B10	2	S1	100	100			200	40A	1.1	25ma	100	25A	SHEJ
S16B20	2	S1	200	200			200	40A	1.1	25ma	200	25A	SHEJ
S16B30	2	S1	300	300			200	40A	1.1	25ma	300	25A	SHEJ
S16B40	2	S1	400	400			200	40A	1.1	25ma	400	25A	SHEJ
S16B50	2	S1	500	500			200	40A	1.1	25ma	500	25A	SHEJ
S16B60	2	S1	600	600			200	40A	1.1	25ma	600	25A	SHEJ
S16B80	2	S1	800	800			200	40A	1.1	25ma	800	25A	SHEJ
S16B100	2	S1	1000	1000			200	40A	1.1	25ma	1000	25A	SHEJ
SCR71	5	S1	25	25			16	65C	.86	6500	25	25	GECB
SCR72	5	S1	50	50			16	65C	.86	6500	50	25	GECB
SCR73	5	S1	100	100			16	65C	.86	6500	100	25	GECB
SCR74	5	S1	150	150			16	65C	.86	6500	150	25	GECB
SCR75	5	S1	200	200			16	65C	.86	6000	200	25	GECB
SCR76	5	S1	250	250			16	65C	.86	5500	250	25	GECB
SCR77	5	S1	300	300			16	65C	.86	5000	300	25	GECB
SCR78	5	S1	400	400			16	65C	.86	4000	400	25	GECB
SCR91	5	S1	25	25			50	80C	1.25	6500	25	25	GECB
SCR92	5	S1	50	50			50	80C	1.25	6500	50	25	GECB
SCR93	5	S1	100	100			50	80C	1.25	6500	100	25	GECB
SCR94	5	S1	150	150			50	80C	1.25	6500	150	25	GECB
SCR95	5	S1	200	200			50	80C	1.25	6000	200	25	GECB
SCR111	5	S1	25	25			70	100C	1.25	6500	25	25	GECB
SCR112	5	S1	50	50			70	100C	1.25	6500	50	25	GECB
SCR113	5	S1	100	100			70	100C	1.25	6500	100	25	GECB
SCR114	5	S1	150	150			70	100C	1.25	6500	150	25	GECB
SCR115	5	S1	200	200			70	100C	1.25	6000	200	25	GECB
SOD100BF		S1		100			2.0	100	1.0	5000	100	25	SOD
SOD100KF		S1		100			5.0	100	1.5	3000	100	25	SOD
SOD200BF		S1		200			2.0	100	1.0	5000	200	25	SOD
SOD200KF		S1		200			5.0	100	1.5	3000	200	25	SOD
SOD300BF		S1		300			2.0	100	1.0	5000	300	25	SOD
SOD300KF		S1		300			5.0	100	1.5	3000	300	25	SOD
SOD400BF		S1		400			2.0	100	1.0	5000	400	25	SOD
SOD400KF		S1		400			5.0	100	1.5	3000	400	25	SOD
T	2		600	420	800	1.5	.80	25	1.5	25	600	25	INRJ
VA723A	2	S1	250	177			1.5	150A	1.1	300	250	150A	EEVB
VA723B	2	S1	200	142			1.5	150A	1.1	300	200	150A	EEVB
VA723C	2	S1	150	106			1.5	150A	1.1	300	150	150A	EEVB
VA723D	2	S1	100	71			1.5	150A	1.1	300	100	150A	EEVB
VA723E	2	S1	50	35			1.5	150A	1.1	300	50	150A	EEVB
VA724A	2	S1	250	177			.75	150A	1.0	300	250	150A	EEVB
VA724B	2	S1	200	142			.75	150A	1.0	300	200	150A	EEVB
VA724C	2	S1	150	106			.75	150A	1.0	300	150	150A	EEVB
VA724D	2	S1	100	71			.75	150A	1.0	300	100	150A	EEVB
VA724E	2	S1	50	35			.75	150A	1.0	300	50	150A	EEVB

UNDER USE
1 - General Purpose
2 - Power Rectifier
3 - Magnetic Amplifier
5 - Controlled Rectifier
6 - Dual Rectifier
7 - Controlled Forward Conductance
8 - High Voltage Rectifier
9 - Bridge Rectifier
⍁ - Revised Specifications
∅ - Insulated Base
Δ - Direct Tube Replacement
† - Pair
‡ - Forced Air Cooling

OTHER
4 - For half wave resistance lead average over 1 cycle

REVERSE CURRENT
⍁ - Dynamic

MFR
6 - Available in Stack form from Mfr.

FOLLOWING ANY TEMPERATURE READING
A - Ambient
C - Case
J - Junction
S - Storage
Δ - Inlet temperature of coolant

APPLICATIONS ENGINEERING DIGESTS

APPLICATIONS ENGINEERING DIGEST NO. 74

Circle 198 on Reader Service Card

Thermal Resistance and Power Dissipation; Rheem Semiconductor Corp., Mountain View, Cal. (K. Crandall)

Thermal resistance is defined as the temperature rise across a material caused by power flow through it, just as electrical resistance relates voltage drop to current flow. In a thermal system, the quantities of interest and their electrical analogues are temperature and voltage, power and current. The unit of thermal resistance is the °C/watt which is analogous to the ohm = volt/ampere. In practice, the effect of thermal resistance is displayed on a thermal derating plot as in *Fig. 74.1*.

The effect of the addition of a heat sink to a transistor can be understood by breaking the total thermal resistance into two series components: $\theta_{J\text{-}C}$ (junction to case thermal resistance), and $\theta_{C\text{-}A}$ (case to air thermal resistance). See *Fig. 74.2*. The effect of adding a heat sink is to reduce $\theta_{C\text{-}A}$, which in turn reduces the total thermal resistance from the junction to the air. An example is given to illustrate how junction temperature is reduced by the addition of the heat sink.

It should be noted that the maximum power dissipation given by the data of *Fig. 74.1* is for steady-state conditions. In pulse applications where the "on" duty cycle is low, the instantaneous power dissipation may exceed the

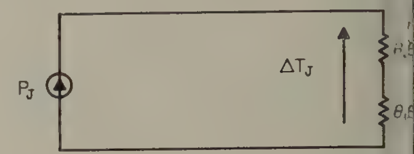


Fig. 74.2—Equivalent thermal circ

steady-state value because of the len of time required to heat the juncti

Example:

$\Delta T_J = P_J\ (\theta_{J\text{-}C} + \theta_{C\text{-}A})$; $T_J = T_A + \Delta$

where ΔT_J = junction temperature r because of dissipated power

P_J = power dissipated in jun tion

$\theta_{J\text{-}C}$ = junction-to-case therm resistance

$\theta_{C\text{-}A}$ = case-to-air thermal resistance

T_J = actual junction tempera ture

T_A = ambient temperature

Let $P_J = 500\ mw$, $T_A = 25°C$, TO-5 tra sistor in free air

$$\theta_{J\text{-}C} = 30°C/W$$
$$\theta_{C\text{-}A} = 157.5°C/W$$
$$T_J = T_A + P_J\ (\theta_{J\text{-}C} + \theta_{C\text{-}A}) = 25°C + (.5\ W \times 187.5°C/W) = 118.8°C$$

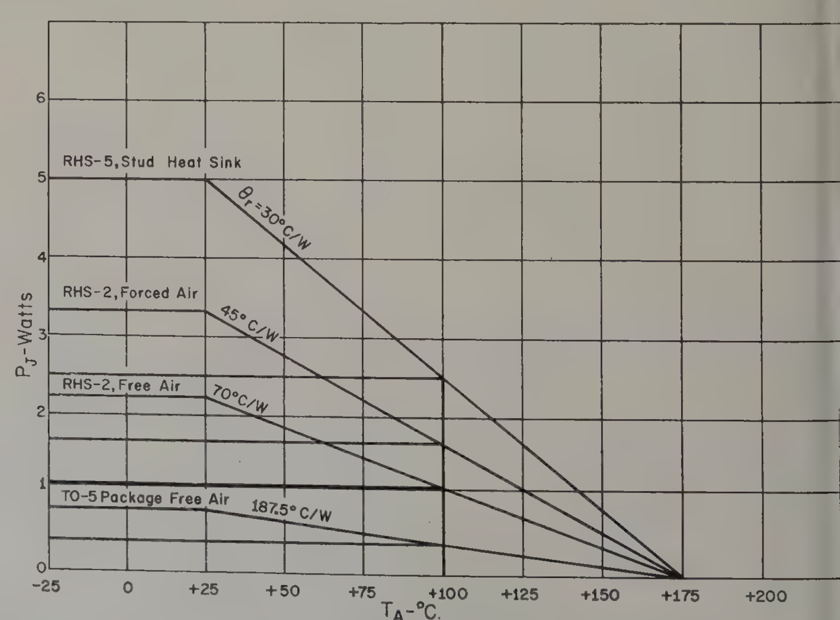


Fig. 74.1—Thermal derating curve.

Study of Gain Control

(From page 43)

AT transistor with various low freuency amplifier load resistors would e similar to those for the MADT as own in Fig. 11.

Fig. 14 shows the response of the amifier using the MAT transistor as the edback component and a 2.2K load esistor. This graph indicates that only db of feedback can be obtained with e 2.2K ohm load as compared to 30 with 12K.

Low Frequency Response

Although the primary interest of this udy was in the high frequency reonse of the amplifier it should be oted that the low frequency response limited primarily by the by-pass and oupling capacitors. The values of these apacitors indicated in Fig. 6 are large nough to satisfy most low frequency equirements.

Feedback Transistor Requirement Summary

It has been noted that not all transtors satisfy the requirements of a eedback transistor in the circuit of Fig. The necessary requirements are:

1) Low collector to emitter (output) capacitance (C_{oe}). This requirement is fulfilled by high frequency transistors.
2) Low collector to emitter saturation voltage ($V_{CE\ SAT}$).

The low output capacitance should ary in such a manner as to decrease e response of the amplifier in the ame proportion as the decreasing outut resistance (r_{oe}) increases the reponse. A 2N393 for example, has an utput capacitance which most nearly atisfies this requirement.

The saturation voltage of the feedack transistor should be low enough o that the transistor does not become aturated during any part of the colector voltage swing. That is to say, for ny desired amount of feedback, the -c feedback resistance must remain onstant. If saturation is reached the eedback impedance will vary with the mplitude of the signal. Again, an MAT atisfies this requirement.

Summary and Conclusions

In low frequency amplifier circuits utomatic gain control can be obtained vithout greatly affecting the frequency esponse of the amplifier.

The transistor configuration shown in ig. 6, utilizing a transistor as a voltage eedback resistance was extensively inestigated. The output capacitance and he collector to emitter saturation voltge are the most important charactertics to be considered in the selection f a transistor feedback component. The N393 possesses the desired combinaion of these characteristics so that it nakes an excellent feedback transistor.

Audio transistors have a high output capacitance (collector to emitter) which increases rapidly as the transistor is driven toward saturation. The result of the increasing output capacitance is a continual decrease in the amplifier high frequency response as feedback is increased. An MADT transistor nearly retains the response of the amplifier (Fig. 9) but since the saturation voltage of the MAT unit is lower, more feedback can be obtained using it as the feedback component. (30 db compared with 15 or 20 db for the MADT unit). Load resistance values can be increased to increase the amount of feedback which can be obtained.

Changing the operating point of a transistor to obtain agc changes its frequency response; this occurs when an agc voltage is applied directly to the base of the low frequency amplifier.

A diode can be used as a variable resistance in agc circuits as a variable load, as a variable shunt or as a variable feedback component. Diodes, however, can only be used with extremely small signals because their resistance follows large signal changes causing distortion.

Three transistors can be utilized for a low frequency amplifier (Fig. 5) with current feedback as the method of gain control. This configuration, however, requires a power drain even with no agc voltage applied and it requires that three transistors be used.

The circuit of Fig. 6, used with a 2N393 as the feedback component is the circuit which more nearly retains the frequency response of a low frequency amplifier and which allows the most feedback to be obtained. It is this circuit and transistor which is recommended for best results in a low frequency automatic gain control circuit.

Market News . . .

Sales

The U.S. Department of Commerce, BDSA, has reported that the estimated shipments of semiconductors by U.S. producers for the first quarter of 1961 was 15% higher in volume and only \$2 million dollars more in value than in the fourth quarter of 1960. The following table shows the dollar value at \$146 million and the volume at nearly 113 million units.

Estimated Shipments of Semiconductors during the First Quarter of 1961 1/

	Quantity (in thousands of units)			Value (in thousands of dollars)		
Category	Total	Military	Non-military	Total	Military	Non-military
Semiconductor Devices	112,682	28,339	84,343	146,039	59,953	86,086
Diodes and rectifiers	60,419	20,278	40,141	41,946	18,615	23,331
Germanium diodes and rectifiers	37,721	11,688	26,033	13,352	5,387	7,965
0-100 ma	33,868	2/	2/	11,541	2/	2/
Over 100 ma	3,853	2/	2/	1,811	2/	2/
Silicon diodes and rectifiers	22,698	8,590	14,108	28,594	13,228	15,366
0-100 ma	8,401	4,838	3,563	10,535	6,887	3,648
Recovery time: none, or over 0.1 usec	6,347	3,530	2,817	6,357	3,962	2,395
Recovery time: 0.1 usec and less	2,054	1,308	746	4,178	2,925	1,253
101 ma—1.4 amps	12,094	3,155	8,939	10,998	3,567	7,431
Recovery time: none, or over 0.1 usec	10,861	2,973	7,888	9,342	3,187	6,155
Recovery time: 0.1 usec and less	1,233	182	1,051	1,656	380	1,276
1.5 amps—7.5 amps	452	241	211	1,187	591	596
Over 7.5 amps	1,751	356	1,395	5,874	2,183	3,691
Special semiconductor devices	10,887	1,745	9,142	19,684	7,897	11,787
Voltage regulator diodes	2,207	979	1,228	8,156	3,707	4,449
0-550 mw maximum dissipation	1,429	742	687	3,832	1,996	1,836
Over 550 mw maximum dissipation	778	237	541	4,324	1,711	2,613
Voltage reference diodes	204	77	127	1,372	550	822
Multi-layer devices (controlled rectifiers, PNPN diodes, and related devices)	295	56	239	2,338	694	1,644
Microwave diodes (mixers and detectors) and variable capacitance diodes (parametric diodes, harmonic generators, etc.)	803	464	339	2,024	1,556	468
Light sensitive semiconductor devices 3/	363	34	329	2,984	1,066	1,918
Other special semiconductor devices 4/	7,015	135	6,880	2,810	324	2,486
Transistors	41,376	6,316	35,060	84,409	33,441	50,968
Germanium	37,810	4,150	33,660	55,157	13,093	42,064
0-999 mw	34,985	3,742	31,243	45,553	10,354	35,199
0-29.9 mc	26,997	2,560	24,437	25,128	4,882	20,246
30-149.9 mc	5,444	531	4,913	9,780	1,876	7,904
150 mc and over	2,544	651	1,893	10,645	3,596	7,049
1 watt and over, all frequencies	2,825	408	2,417	9,604	2,739	6,865
Silicon	3,566	2,166	1,400	29,252	20,348	8,904
0-999 mw	1,973	1,221	752	12,629	8,272	4,357
0-29.9 mc	1,631	978	653	9,996	6,395	3,601
30-149.9 mc	321	231	90	2,302	1,657	645
150 mc and over	21	12	9	331	220	111
1-9.9 watts, all frequencies	1,133	845	288	12,364	8,963	3,401
10 watts and over, all frequencies	460	100	360	4,259	3,113	1,146

1/ Estimated total industry shipments including intra-plant and inter-plant transfers.
2/ Withheld to avoid disclosing the operations of individual firms.
3/ Includes solar cells, infra-red detectors, photoconductive cells, photovoltaic devices, photodiodes, photoelectric-magnetic devices, and the like.
4/ Includes diodes and rectifiers of selenium, copper oxide and other materials; tunnel diodes; thermoelectric semiconductor devices; and others not elsewhere classified.
Source: The quarterly Joint Survey of Production Capabilities for Electronic Parts conducted by the Electronics Production Resources Agency of the Department of Defense, and the Electronics Division, BDSA.

Japanese exports of transistors to the United States during the first quarter of this year, according to the Ministry of Finance, was 975,000 units. This was an increase of over 2½ times the 386,000 figure for the same period in 1960. During 1960 U.S. exports of semiconductors to Japan totaled \$1,154,000.

Factory sales of transistors increased by more than 2.7 milli and total value of units sold by more than \$1 million in Ju according to the figures released by the Electronic Indus Association's Marketing Data Department.

	Factory Sales (Units)	*Factory Sales (Dollars)*
June	17,899,005	\$26,148,746
May	15,128,181	25,113,042
April	15,072,064	27,388,278
March	15,129,273	29,815,291
February	13,270,428	25,699,625
January	12,183,931	22,955,167
Jan.-June '61	88,682,882	\$157,120,149
Jan.-June '60	60,485,683	\$152,932,961

Johnson & Hoffman Manufacturing Corporation, Mineola, N York, manufacturers of precision metal stampings and dee drawn parts, has appointed the following sales representativ Robert Awig & Associates, Cleveland, Ohio; A. V. Doran Co pany, St. Louis, Missouri; The Alfred A. Lee Company, Phoen Arizona; Nero Electronic Sales Corporation, Wilmette, Illin Steele Technical Sales, Winter Park, Florida; and Armstro Sales, Inc., Cincinnati, Ohio.

Semi-Alloys Inc. has announced the appointment of t Wexler-Court Sales Corporation as their representative for t eastern half of the United States from Minneapolis throu Boston and New York.

The Lansdale division of Philco Corp., has opened a new sem conductor sales office in Englewood, Col.

Suppliers

General Instrument Corp.'s semiconductor division has d continued all production of silicon mesa transistors and is n converting to a full line of silicon epitaxial planars in TO- and TO-5 packages. The firm has also announced the avail bility of a line of silicon rectifier replacements. Types IN12 IN2630, IN570, IN1150, IN2389 and IN2490 are designed with 4, 5 pin as well as octal bases. These units are priced at \$11.50 ea in lots of 100 and up.

Electronic Metals and Alloys, Inc., Watertown, Mass., has a nounced the availability of clad material with 99.999+% pu gold at standard clad prices.

Kewaunee Scientific Equipment, division of Kewaunee Man facturing Co., Adrian, Mich., has available a welder enclosu for manufacturing semiconductors.

Dow Corning's silicon division, Hemlock, Mich., is offering new packaged one-piece crucible charge in diameters up to 1 inches. Advantages claimed for the crucible charges are that th have not been cast and have not come in contact with any co tainer, and can be used directly out of the package witho being cleaned.

Semi-Alloys, Inc., Mt. Vernon, N.Y., has developed a stam ing process which produces flat, intricately shaped pellets an washers from semiconductor materials with thicknesses as lo as 250 millionths of an inch.

Financial

Sprague Electric Company, North Adams, Massachusetts, h declared a quarterly dividend of 30 cents per share on the Co pany's common stock, payable to the stockholders of record the close of business on August 30, 1961.

ERRATA

In our August 1961 Market News section, on page 18, und the heading "Sales," we published a table of "Estimated Shi ments of Semiconductors, during 1961." The correct heading f the table is, Estimated Shipments of Semiconductors, during 196

ndustry News (R&D)

from page 17)

A highly sophisticated flat rectangular enclosure, suitble for Multi-element Components, thin film circuits and olid state circuits, is under development at Philco Corp.'s Iicroelectronic Department laboratories. The 2-D enlosure features a true glass-to-metal hermetic seal, rather han a solder seal. A microelectronic device can be mounted irectly on the metal plate which forms the base of the ackage. According to William F. Long, manager, Microlectronics Department, Lansdale Division, efficient heat issipation is provided and hot spots are eliminated, since ne metal plate can be mounted on an external heat sink. Ie stated that the number of leads and package dimenions can be varied to conform to a particular miniaturizaon approach, such as the printed circuit, micro module, nd welded (stacked) mounting techniques.

A pulsed ruby optical maser has been operated as a ght amplifier by Bell Telephone Laboratory scientists. In ne experiment, two ruby masers were set up in tandem. pulse of light from one maser, operating as an oscillator, 'as beamed into the other. Amplification of the light by a ıctor of two was observed. The two rubies were fired siıultaneously. The output from the amplifying ruby was ıeasured by a photomultiplier tube. Both the signal going ıto the amplifier and the signal coming out were dislayed on a dual-beam oscilloscope. Gain was measured y comparing the output-to-input ratio when using the mplifier to that obtained when the amplifier was removed om the beam. The amount of gain that can be obtained epends on the temperature of the amplifying maser and ne pumping power. A net gain of a factor of two was obrved at —40°C.

The application of semiconductor physics to piezoelectric ceramics was one of the key developments in piezoelectricity discussed recently in Chicago by Dr. Hans Jaffe, director of electronic research for Clevite Corporation, Cleveland. Speaking before the 140th annual meeting of the American Chemical Society, Dr. Jaffe said that the control of excess electrons has been recognized as of major importance in improving piezoelectric ceramics. "The semiconductor phenomena in these materials exert a strong influence on their piezoelectric properties," he said, "and we are developing techniques to control them by doping in much the same way that semiconductor materials are doped." Dr. Jaffe said that the new techniques have done much to make possible major developments in the piezoelectric field, a new 20,000-volt ignition source, radio frequency filters that can greatly improve the performance of transistor radios and transducer elements for sonar and ultrasonic devices that provide superior power handling capacity. He also discussed the recent observation of strong piezoelectric effects in such semiconductor crystals as cadmium sulfide and zinc oxide. Work in this area is continuing at major laboratories around the country. Both semiconductor and piezoelectric fields can be expected to continue to benefit greatly from the new scientific insight which is resulting from the interplay of the two disciplines, said Dr. Jaffe.

A new silicon transistor that can perform the jobs of up to 40% of the more than 2,000 transistor types now on the market has been developed by RCA. The new unit is adaptable to a wide variety of uses in the complex electronic circuits of military weapons and communications systems, industrial control devices, data processing equipment, and high quality consumer products. A company spokesman stated, "we have succeeded in wedding triple

diffusion and planar manufacturing techniques, both rela tively new and highly exacting processes, in a single tran sistor. Along with other techniques, they have combin to give the 2N2102 phenomenal powers for amplifyin switching or regulating current flow. In addition, they a ford the device great electrical stability and reliability."

Eric Kolm, president of U. S. Sonics, Inc., maker piezoelectric ceramics, has announced the development a solid state 455 KC ceramic filter, paper-thin and no b ger in diameter than a lead pencil. It is designed to repla the standard mechanical transformer which goes into eve receiving set and promises to be a signficant breakthrou in the manufacture of radio and TV sets, as well as oth types of communication equipment, Mr. Kolm predic

The tiny i-f filter makes it possible to tune to one stati at a time, instead of receiving all transmissions simult neously. Encased in its pea-sized "can", with lead-wir attached, it is fully adaptable to automated assembly tec niques. The ceramic filter cannot get out of tune, and w serve, highly resistant to physical shock and variations temperature, for the life of the set. Additionally, it offe superior performance in being much less susceptible "microphonics," or unwanted sound waves, than the co ventional transformer, according to the company. Initiall U. S. Sonics is building two types of the new filter. One for transistor circuits; the other is designed for use wi vacuum tubes.

A thermoelectric generator, developed by Westinghou Electric Corporation, has been put into service to prote a mile-deep gas well of El Paso Natural Gas Compar El Paso, Tex. The generator, installed in a remote regi of the San Juan Basin, northeast of Farmington, N. Me supplies the electric power needed to prevent self-corr sion of the well's steel casing. The technique, known cathodic protection, keeps the casing from being eat away through an electrochemical reaction that occu spontaneously in metal objects buried in the ground. T thermoelectric generator taps a small amount of the g coming from the well, burns it, and converts the he directly into the electricity that safeguards the well.

The thermoelectric generator is connected between t 5000-foot gas well casing and a ground bed consisting silicon cast iron anodes packed vertically in a hole 2 feet deep. It reverses the normal flow of current set by the casing as it chemically reacts with the soil. Th the easily replaceable ground bed is slowly eaten aw instead of the casing itself.

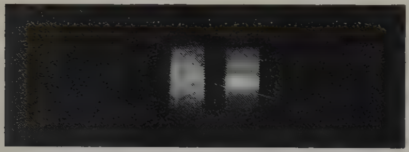
Protection of the well casing is accomplished with abo six amperes of current at eight volts d-c. This power generated at a temperature of 800° F on the hot side the generator. The cool side of the unit operates at 200° higher than the boiling point of water at the 6100 fo elevation at which the generator operates.

A Trion Instruments, Inc., laser, operated by four Un versity of Michigan physicists, has produced a cohere beam in the blue region for the first time. By focusing t laser's output beam (6943 Angstroms) into a quartz cry tal, the second harmonic (3471.5 Angstroms) was detect The second harmonic was produced by the high intensi of the laser beam at the focus, utilizing the non-line optical properties of quartz. Output power of this syste is greater than two joules per pulse. "We are emphasizi the development of electronic components in the optic region," Douglas L. Linn, company president said, "b cause we feel that these devices will find many applic tions similar to those for which devices in the microwa and radio-frequency region are now used."

New Products

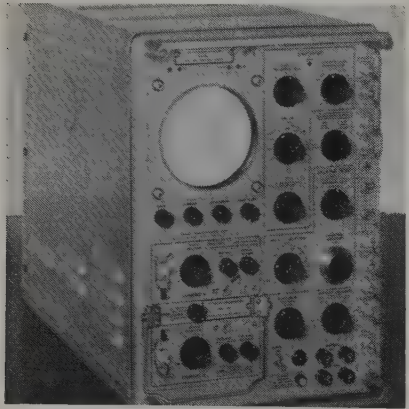
Bar Solder

A new bar solder that has been effective in cutting printed circuit joint rejects from 8 in 400 to 1 in 5,000 is available from Alpha Metals, Inc. called "Alpha Vaculoy (R) Bar Solder," photomicrographs indicate that it is significantly freer from oxide-forming elements and as a result, cuts dross, increases bath life, reduces inherent inclusions, improves wetting and produces brighter joints. It is said to provide more finished units per pound, and is available from stock in most of the common tin-lead alloys; it comes in standard 1 lb. bars, or 9 lb. ingots for automatic soldering machines.



Left, standard solder. Right, bright, clean oxide-free Vaculoy (R) Bar Solder.
Circle 113 on Reader Service Card

Environmentalized Oscilloscope



A new environmentalized oscilloscope with sweep-delay feature, Tektronix Type 945, with Type MC Dual-Trace Preamplifier plugged into the vertical channel permits highly precise measurements under severe environmental conditions in the dc-to-24 mc region. Temperature: −40°C to 55°C/71°C (operating), −65°C to +85° C (storage). Humidity: 10 days, 95% RH 18°C to 65°C (storage). Fungus: 28 days (storage). Vibration: 5 G's, 55 cps, 0.030" pk-pk. (operating). Shock: 400 lb. hammer drop (operating). Altitude: 20,000 ft. (operating), 50,000 ft. (storage). Radio Interference: 15 kc to 400 mc (operating). Salt Atmosphere: 100 hrs (finishes). Rain: 5 min. drip test (storage).
Circle 108 on Reader Service Card

Tantalum Capacitors

A new series of improved 125° C 'cup style' sintered-anode tantalum capacitors is available from the Sprague Electric Company. The new units supplement the 85°C ratings previously available from Sprague. Three case sizes are furnished. In the smallest case size, ratings range from 30μF at 4 volts to 1.7μF at 85 volts; in the middle case size, capacitances range from 140μF at 4 volts to 9μF at 85 volts; and the largest case size capacitances range from 320μF at 4 volts to 25μF at 85 volts. All units are available in both ±10% and −15+20% tolerances.
Circle 112 on Reader Service Card

Photoconductors

A new line of photoconductor devices was introduced by Sylvania Electric Products Inc. The new units consist of a cadmium sulfide cell (below left) on which "comb-shaped" electrodes have been deposited. The spectral response of cadmium sulfide closely approximates that of the human eye. Such response is preferred in most photoconductor applications. The comb-shaped design maximizes the area of sensitive material while maintaining close electrode spacing. The devices are hydrogen-filled, assuring uniformity and stability of characteristics. Use of a hermetic glass seal increases cell life by keeping out moisture and other foreign matter which might destroy photoconductor properties.
Circle 111 on Reader Service Card

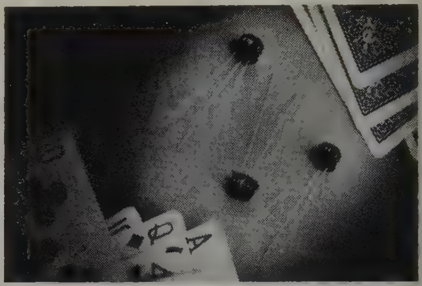
Limit Switch

A new limit switch featuring solid state electronics and high reliability has been introduced by the Apparatus Division of Texas Instruments Incorporated. A life test that commenced several months ago is continuing with the switch nearing 40,000,000 trouble-free cycles. The new unit, called the Statronic Limit Switch, requires Standard 115 V a-c input power and has an operating temperature range from 0° to 200° F. It is impervious to moisture and corrosive atmospheres.
Circle 129 on Reader Service Card

Epitaxial Mesa Transistors

The Lansdale Division of Philco Corporation has introduced silicon diffused n-p-n epitaxial Mesa transistors that combine high voltage and high power ratings with low storage time and low saturation voltage. Featuring very high gain bandwidth product (f_T), 2N2086 and 2N2087 permit design of circuits with switching rates greater than 15 mc at currents as high as 300 ma. Specifications of the 2N2087 are: BV_{CBO}-120 v. min; h_{FE}-40, min; V_{CE} (sat)-0.5 v, max; maximum rise, storage and fall time (circuit gain of 10) of 85, 100 and 55 nsec. max; and gain bandwidth product (f_T) of 150 mc, min.
Circle 100 on Reader Service Card

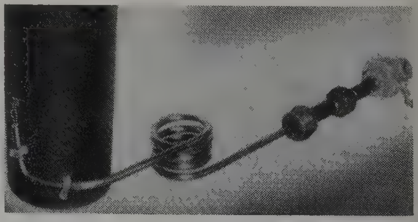
Germanium Transistors



Three new germanium transistors introduced by General Electric are expected to be a boon for protection in existing marginal high-voltage circuit designs. 2N1924, 2N1925 and 2N1926, in addition to voltage ratings up to 60-volts, have a high gain characteristic. Thus, they may be used in audio frequency switching circuits as well as high voltage amplifier circuits.
Circle 109 on Reader Service Card

Thermocouple Assembly

An all stainless steel thermocouple assembly with a small pad welded at the hot junction has been developed by Trin-



ity Equipment Corp., for skin temperature sensing. In use, the pad and sheath will be welded to large diameter heater tubes and accurately transmit temperature measurements. The assembly has been designed coiled to allow for expansion and contraction of the heater tubes. The flexible metal-sheathed thermocouple element, called "Trinox", consists of a swaged sheath containing thermocouple wire and magnesium oxide insulation.
Circle 104 on Reader Service Card

Automatic Zone Refiner

A big step toward automating the production of semiconductors is announced by Lindberg Engineering Company in its new fixture for the continuous zone re-

fining of germanium. The unit consists of an atmosphere charging chamber where a number of germanium-filled boats are placed on an indexing conveyor. The boats then are automatically charged into a quartz tube where multiple zones can be melted either by induction or resistance heating elements.

Circle 103 on Reader Service Card

Transistor Test Set

A new transistor test set designed to test extremely low leakage currents has been developed by Fairchild Semiconductor. Essentially a go/no go tester, but with absolute readout capability, the 1193 will test leakage currents from 1 picoamp (1 micromicroamp) to 1 microamp for both n-p-n and p-n-p transistors. It has an accuracy better than plus or minus 1% above 10 picoamps and plus or minus 5% below 10 picoamps. The unit can be programmed for collector-to-base and emitter-to-base voltages from 0-100 volts in 1 volt steps.

Circle 119 on Reader Service Card

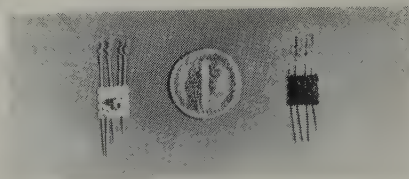
Temperature Chamber

Delta Design, Inc. has announced the addition of a large volume-low gradient model to their line of quality temperature chambers. Model 1060B chamber has temperature profile characteristics suitable for Mil. Spec. testing of large assemblies where temperature variation throughout the specimen, including gradient, control variations, and drift is not to exceed $\pm 1°C$. The unit operates in the temperature range of $-100°F$ to $+500°F$. Fast cool down time is achieved through use of convenient bottle CO_2 and the unit may be automatically cycled between two temperatures with the MR-1 Automatic Time Sequencer.

Circle 116 on Reader Service Card

Microminiature Flip-Flop

General Instrument Semiconductor Division announces development of a microminiature flip-flop, consisting of 12 pre-



selected, unencapsulated components, each passivated by a silicon oxide film and mounted on a ceramic substrate measuring only 0.310 x 0.310 inches. Expected to be used initially in computer circuits for satellite and missile applications, the device operates at speeds in the nanosecond range. The flip-flop contains the following microminiature components: six semiconductor resistors, two silicon dioxide capacitors, two epitaxial planar transistors and two fast-switching planar micro-diodes.

Circle 115 on Reader Service Card

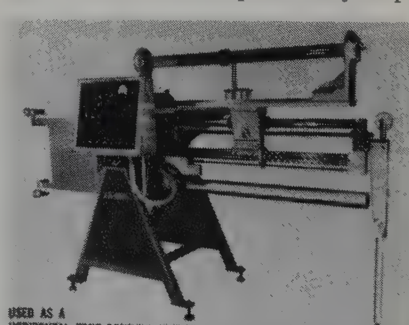
Fast-Switching Silicon Diode

A new kind of silicon diode, the RD750, was introduced by Rheem Semiconductor Corporation. With a 5-to-1 improvement in conductance and a 2-to-1 improvement in recovery time, the new product is said to make possible significant design improvements in computers and other electronic systems. Conductance is typically 1,000 ma at one volt, permitting new levels of high-current switching for applications such as thin-film computer memories. At low current levels the voltage drop is very low, being only 0.65 volt at 10 ma. Power dissipation is 750 mw. Reverse time is typically as little as 10 nanoseconds.

Circle 120 on Reader Service Card

Horizontal Zone Refining Attachment

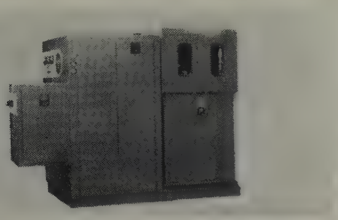
Lepel High Frequency Laboratories, Inc. has added a new Horizontal Zone Refining attachment to their Floating Zone and Crystal Pulling fixture. This versatile 3 in 1 unit is particularly help-



ful in research and development laboratories conducting experimental work related to materials science. This attachment is easily mounted on the original basic unit containing the traverse and programming mechanism. The control panel on the basic unit also operates the induction generator. The change from floating zone operation to horizontal zone refining to crystal growing operations requires less than a half hour.

Circle 110 on Reader Service Card

"High Power" Induction Heater



Induction Heating Corporation has introduced its new 450 kc induction heater designed for a wide range of jobs in industry. Rated for continuous duty at 150 KW, sufficient reserve power is "built-in" to deliver full output at distances up to 40 feet from the generator. It is an easy-to-use reliable unit, and its design features uncomplicated installation, ready accessibility for maintenance, push-button operation, and an output transformer that provides simple work-coil matching, depending on the job. Thermostatic controls keeps raw water consumption at a minimum.

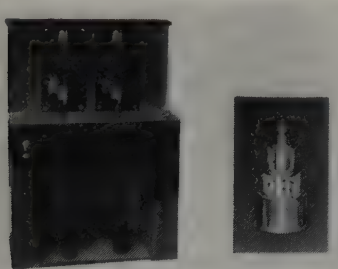
Circle 106 on Reader Service Card

Vertical Alloying Furnace

Research Instrument Co., Inc., vertical alloying furnace has very high batch capacity. Production rate is comparable with that of average type conveyor furnaces used in the semiconductor industry. Stacking arrangement with properly designed jigs can permit as much as 3000 starts per batch. Vertical stacking zone is 2" rd. by 8" high. Temperature range to 1000° C. Inconel Muffle and Pedestal. Floor area required is approx. 2½' x 2½'.

Circle 126 on Reader Service Card

High Frequency Sealing Machine



Kahle Engineering Company announces production of a new 2-position high frequency sealing machine, No. 1243. In this case the parts to be sealed together are three metal pieces with two glass pieces between. All of these seals are made simultaneously in one operation. The sealing operation itself takes about 8 seconds and is regulated by a precision timer control unit. The two positions may be used alternately and may be for different assemblies. Spacing of all parts is precise within a few thousandths of an inch.

Circle 102 on Reader Service Card

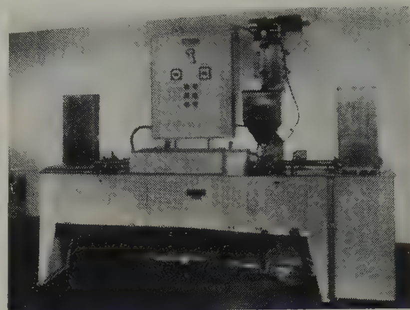
Heat Sink Kit

A Heat Sink Kit (Astrokit Series A) containing seventeen natural convection, conduction, and forced convection (including fan) units together with three sets of mounting kits and a supply of interface grease is now available to engineers from Astro Dynamics. The heat sinks furnished provide a range of thermal resistance to cover all possible transistor applications.

Circle 136 on Reader Service Card

Coating Machine

High production application of plastic powders to axial lead components can be accomplished by Conforming Matrix Corporation's Model PR-1 Powdered Resin



Coating Machine. Used in conjunction with the CM Model TL-1 Tray Loader and CM Magazine Loader, components are placed in trays, suitable to the range of sizes being run, which are loaded in magazines and automatically fed through a radiant heat oven. The components are brought to any desired heat up to 600° F, and passed through a controlled stream of finely ground plastic powder. The heat of the components melts the powder, forming a coating.

Circle 105 on Reader Service Card

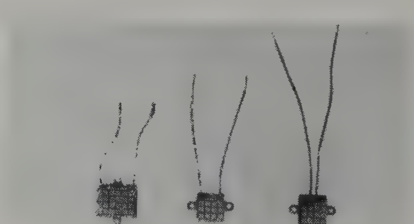
Precision Ground Laboratory Furnaces

L. J. Products, announces their new improved Precision General Laboratory Furnace. These precision temperature controlled general laboratory and heat treating furnaces feature the accurate meter-relay type temperature control, virtually eliminate electrical switching noise generation by the use of solid state switches to control the heater load and can be used where noise must be kept to a minimum. Available in sizes with working volumes of 4½" x 4½" x 4½" to 8¼" x 8¼" x 8¼" and with temperature range from 250° F to 2200° F. All models operate on 115 V a-c, 50-60 cps power. Models for 230 volt operation are available on request.

Circle 107 on Reader Service Card

Thermoelectric Cooling/Heating Modules

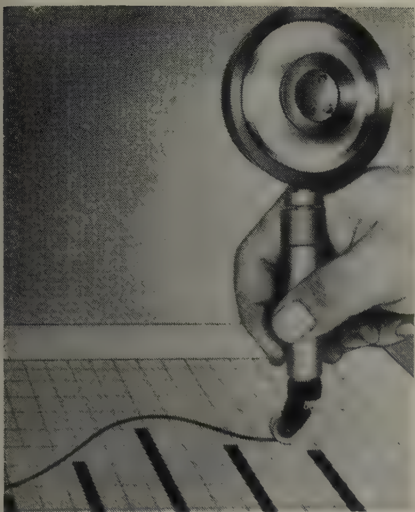
A new line of thermoelectric modules which uses 1/10 the amount of current normally required to do an equivalent job of cooling or heating has been engineered by Jepson Thermoelectrics, Inc.



Operating Current (d-c): Model 615, 0-3.5 amps; Model 629, 0-3.5 amps. Operating Voltage: Model 615, 0-2 VDC; Model 629, 0-4 VDC. Max. Heat Pumping Capacity: Model 615, 4.25 watts; Model 629, 8.6 watts. Max Delta T (module mounted on +20°C sink), in open air: 60°C, in vacuum: 74°C Max. Operating Temperatures: −130°C to +125°C.

Circle 127 on Reader Service Card

Tape Pen



A new drafting instrument, for fast, accurate application of self-sticking tapes to charts, printed circuit masters and other graphic illustrations is announced by W. H. Brady Co. With the Brady Quik Line Tape Pen you can apply straight, curved or irregular lines from 1/32" to 2/16" wide. You can draw with tape on any surface on which you can draw with ink, and on most surfaces that can't be inked. Lines are uniform in width and density. They are accurate for placement to 0.010 of an inch.

Circle 117 on Reader Service Card

Proportional Power Magnetic Amplifier

Hevi-Duty Electric Company, has developed a proportional power magnetic amplifier for precise electrical control applications. Coupled with a standard saturable core reactor, the new amplifier is the electrical equivalent of an equal percentage valve, in that a linear change in the system input will produce a percentage change in process power. This system can control the temperature of an electric furnace with a high degree of accuracy. Type 300 SRMA D 73312 operates from a 110-volt, single-phase, 60-cycle line with an 0-5 ma input, from any automatic controller installation. The output from the magnetic amplifier is normally 0 to 85 volts d-c.

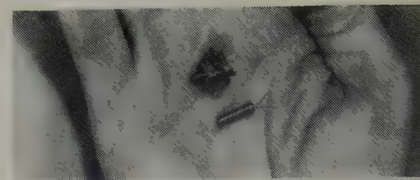
Circle 101 on Reader Service Card

Transistor Radiator/Retainers

Double-ended combination radiators and retainers for mounting TO-5, -8, -9, -11, -12, -29, -33, -37, -38, -39, -42, -43 and other transistors are available from The Birtcher Corporation/Industrial Division. In addition to conventional mounting requirements, the devices have a tapped base for quick mounting in a flip-flop or push-pull circuit. Sides of mounting holes are slotted to accept transistor case diameters from 0.310-0.325" and 0.475-0.490". Slotting also allows for tolerance variations of case diameters.

Circle 121 on Reader Service Card

Cryogenic Sensors



Two cryogenic sensors, each about the size of a five-cent piece, have been introduced by Minneapolis-Honeywell Regulator Company. The firm said the tiny sensors are germanium semiconductors designed for application in test and operational phases of space vehicles using liquid helium and nitrogen and for use in calibration and standards laboratories. Their temperature range is 4° to 40° Kelvin (−269°C to −233°C.) One type of sensor measures surface temperatures; the other is a probe-type unit for internal applications. Both are encapsulated and hermetically sealed.

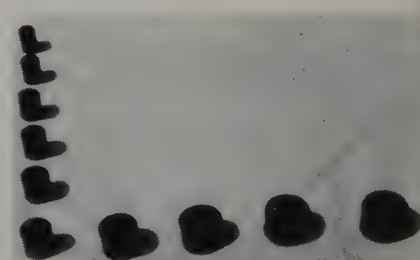
Circle 114 on Reader Service Card

Automatic Measuring System

A new system which digitally measures the elapsed time between any two points on a high-speed waveform is available from Dymec, a Division of Hewlett-Packard Co. DY-5844 Automatic Waveform Measuring System will measure time intervals between any two points chosen from the 0-100% level of either stimulus or response pulse. Accuracy is better than ± 4% of full scale, ± 0.4 nanoseconds. In addition to measuring transistor delay, rise, storage, and fall time, it will make similar measurements on diodes, magnetic cores, and high speed components and circuits.

Circle 118 on Reader Service Card

Epoxy Case Shells



Cycle Products is manufacturing non-burn epoxy shells for the electronic component industry. These cases will find uses in diodes, resistors, delay lines, capacitors, transformers, coils and module packaging. All sizes are available in quantity for immediate delivery. Sizes other than standard and materials other than non-burn epoxy may be had on special order. Moulding to sections as fine as .010 can be done.

Circle 122 on Reader Service Card

Vinyl Industrial Glove

A new disposable industrial glove has been introduced by the Wilson Rubber Co. It is designed for inspection work, small parts handling, and any industrial operation where touch sensitivity is important and either product or hand must be protected. While the new "Tru-Touch" glove is only .006 of an inch thick, it is exceptionally tough, with a tensile strength of 1000 to 1200 psi.

Circle 130 on Reader Service Card

Diffusion Tube Furnace

A new three-zone diffusion tube furnace for tube temperatures up to 2300° F (1260°C.) has been developed by K. H. Huppert Co. As a space-saving feature, the furnaces can be arranged in groups of six on one common base. Each furnace has independent electricals and controls, all located in the base. Down time for maintenance can be held to 15 minutes or less, since each furnace unit is individually replaceable. It is only necessary to disconnect the power leads, slide the "down" unit from the support rack, slide in the replacement unit and reconnect leads.

Circle 135 on Reader Service Card

Power Converters

The Hoover Company, Electronics Division has recently announced a new line of power converters featuring a signifi-

cant improvement in conversion efficiency and claimed to be ideally suited for applications where the power source is a thermoelectric generator, fuel cell, or low voltage battery. The efficiency of the new unit is greater than 75%. A wide range of input and output parameters is available. Complete solid state construction eliminates maintenance considerations. Converters with an input as low as 0.1 volt are practical. Virtually any output, either a-c or d-c, can be supplied.

Circle 124 on Reader Service Card

Mesa Diode Dice

MicroSemiconductor Corporation has announced availability of two standard types of silicon mesa diode dice. MSC-1 (ultra-fast computer diode) has electrical properties of < 2 nanosecond recovery, $< 2\mu\mu f$ capacitance, > 75 volts PIV. The MSC-2 (general purpose diode) has PIV > 300 volts, $< 10 m\mu amp$ leakage. The dice are surface passivated and can meet or exceed MIL-S-19500B specification without any additional sealing. The anodes and cathodes are gold-plated for ease of termination. Approximate size is .020" x .020" x .007" thick.

Circle 134 on Reader Service Card

Beryllium Oxide

Brush Beryllium Company offers beryllium oxide (beryllia) a ceramic material with superior thermal conductivity. It is also chemically inert, extremely refractory, and the best high-temperature reflector and moderator of neutrons. Because of this combination of properties, beryllium oxide opens new avenues to the solution of design problems and for improvement in product performance. Readily metallized and producible in pressed parts such as discs, blocks and plates, B-6 Bodies provide sound high density shapes ideally suited for heat sink applications.

Circle 138 on Reader Service Card

Cooler Kit

A designers' kit containing representative types of Semiconductor Coolers including natural convection units and forced convection modular package is now available from Wakefield Engineering. The Cooler Kit contains both complete units and modular components, enabling a designer to conduct tests using his own circuitry within the physical layout and environment of his choosing. Complete technical data is supplied and a "Handbook" is included which outlines the theory, as well as practical techniques for temperature, power, and air flow measurement.

Circle 123 on Reader Service Card

Vibrating Feeder

Minimus Co., offers their Vibrating Feeder for all small parts from fine powders up to 3/32". The outstanding feature of the feeder is the flexibility made possible by the bowl design. Motor is simple, compact and rugged. Only two controls required, a switch and a rheostat. Feeds one part or a million; low power-low temperature rise; magnetically shielded. High temperature models are available. Only 3" dia. x 2-3/8" high. Weight 1 lb.

Circle 128 on Reader Service Card

Flash Generator

Epic, Inc., Flash Generator SC 2 is a pulse light source unit giving a flash sequence which may be adjusted from 1 to 10 per second. Flash duration is 0.1 microseconds. Flashes are uniform as they are produced by discharge into a tube filled with Krypton and other gases. The instrument is intended chiefly for testing semiconductors or material for semiconductors. No maintenance is required and the discharge tube has a life time of approximately 100 million flashes. Power supply is 110 V 60 cycles and power input is max. 35 W. Dimensions: 14½" x 10½" x 8½". Weight 28 lbs.

Circle 125 on Reader Service Card

Personnel Notes

The appointment of Robert A. Miller as sales manager for specialty plastic films being introduced by Allied Chemical's General Chemical Division is announced by Frank J. Woods, director of sales. With the division 15 years, Mr. Miller was manager of its New York Metropolitan sales office for the past 3 years.

The appointment of William D. Hogan to the newly created position of manager of engineering services for the Semiconductor Division of Sylvania Electric Products Inc. has been announced by Ernest H. Ulm, general marketing manager for the division. Mr. Hogan, who has been manager of field engineering since June 1960, will now coordinate all engineering activities associated with marketing. He joined the company in 1950 as a junior engineer at the division's Engineering Test Laboratory in Boston.

As part of the expanding national distributor sales program of the General Instrument Semiconductor Division, two key divisional appointments have been announced by Clayton Kiernan, National Distributor Sales Manager. Ronald Friedman has been named Distributor Field Sales Manager of the Semiconductor Division, a new post. William Carlson has been appointed Headquarters Distributor Sales Manager of the Division.

John N. Vogt, a nationally recognized authority on the design of equipment for the production of semiconductors, has joined Temperature Engineering Corporation as Vice President in Charge of Manufacturing. Mr. Vogt, for the past 15 years, has served with General Electric Co., helping to pioneer some of the most notable advances in silicon rectifier manufacturing equipment and tooling, and in the establishment of quality control standards for the semiconductor industry.

Francis J. Asip has joined Monsanto Chemical Company's marketing staff as a sales representative in the Inorganic Chemicals Division's electronic products group, J. E. Crawford Jr., division director of marketing, has announced. Mr. Asip, whose headquarters will be at St. Louis, was previously with Allegheny Electronic Chemical Company.

Cary H. Stevenson, Vice President of Lindberg Engineering Company, has announced the recent appointment of Elmer W. Edstrand as Manager of the Kiln Division. Mr. Edstrand's divisional responsibilities will include charge of all sales of the company's line of kilns used throughout the ceramic, as well as other nonmetallurgical industries.

(Continued on page 69)

New Literature

Trinity Equipment Corp., Unitized Dry Air Systems provide a dependable, economical source of super-dry compressed air with dewpoints of —100°F or lower. They are designed for industrial and scientific use in installations with no, or inadequate, source of compressed air. Technical information, along with detailed specifications and system selection charts for determining required capacity at any altitude are contained in company's catalog.

Circle 170 on Reader Service Card

A new brochure describing the analytical methods and processes used for control of materials in the Electronics Industry and describing their facilities and services has been published by Electronic Metals and Alloys, Inc. Request Brochure #28.

Circle 171 on Reader Service Card

A three-color, four-page folder, designed to aid buyers and engineers in the selection of Fairchild Planar Transistors and Diodes, is available from Schweber Electronics. The folder outlines the applications of these transistors and diodes, and defines concisely their construction and specifications in quick-reference, tabular form.

Circle 172 on Reader Service Card

General Electric Company has published a specification sheet, No. 145.15, on the 1N3289-1N3295 high current Silicon Rectifier. The eight-page brochure contains 19 curves including NEMA overload ratings. The Rectifier Components Department has provided detailed recurrent overload information keyed to the "NEMA Standards for Rectifier Equipments Below 100 Kilowatts." The 19 curves depict cell specifications, maximum circuit ratings for cells mounted on 5 x 5 x ⅛" and 7 x 7 x ¼" copper fins and recurrent overload ratings for cells mounted on 7 x 7 x ¼" copper fins.

Circle 173 on Reader Service Card

A brochure which describes and illustrates mechanical and air operated clamps for holding masks and parts, and standard and special fixtures used to speed up production in high quality color decoration of mass produced products is being offered by Conforming Matrix Corporation. Request Form No. 7624.

Circle 174 on Reader Service Card

A new condensed catalog of nanosecond instrumentation has been published by Lumatron Electronics, Inc. The 6 page catalog illustrates and describes a complete line of production and laboratory test equipment designed for use in semiconductor, computer, and high frequency applications. It includes specifications on sampling oscilloscopes, automatic switching time test sets, nanosecond risetime pulse generators, semiconductor test sets and nanosecond delay lines.

Circle 175 on Reader Service Card

John Fluke Mfg. Co., Inc., announces technical data bulletin describing a ne power supply. Rated at 0 to 500 volts, ou put current 0 to 500 ma, the Model 417 is designed for critical situations requi ing precise performance with high pow capabilities.

Circle 176 on Reader Service Card

Slater Electric, Inc., has published data sheet on its new series of miniatu hermetically sealed silicon rectifiers sp cifically developed to replace the larg top hat types IN536 thru 540, IN1095, an IN1096. Bulletin No. ID-101A gives com plete application engineering data c Slater type numbers SLA536, SLA53 SLA538, SLA539, SLA540, SLA1095, an SLA1096. Also included are typical re verse characteristic, and typical forwa characteristic curves.

Circle 177 on Reader Service Card

Networks Electronic Corp. has prepare a new brochure on their glass-to-met seal facilities. The four page booklet d scribes the applications, environment conditions and specifications for glass-t metal seals. Data on standard units is al provided.

Circle 178 on Reader Service Card

Varo Inc., is offering a new catalog c its microcircuitry devices now availab as standard circuits. Featured in th catalog are descriptive data on digit computer, control and audio frequenc circuits. Photographs, complete specific tions, prices and deliveries are also in cluded.

Circle 179 on Reader Service Card

The complete line of McLean Enginee ing Labs packaged blowers, propell fans, centrifugal blowers, ring fans an accessory items is presented in a ne 48-page catalog. All mechanical and ele trical characteristics of each model a included with performance curves an engineering drawings. A special section devoted to basic design information f ventilating electronic equipment usin forced-air cooling. Mathematical formula and graphs are provided for problem pertaining to cooling solid state circuit or tube assemblies.

Circle 180 on Reader Service Card

Monitor Products Company, Inc., an nounces its new 4-page booklet on "Ho to Specify Component Ovens." Th booklet contains and explains all of th requirements necessary to specify over to control the temperature of crystal oscillators, transistors and other temper ature-sensitive components. Included a thermostat characteristics chart show ing the capabilities and limitations o various thermostats. Specifications on Monitor standard ovens are also include to aid in selecting the proper oven.

Circle 157 on Reader Service Card

Personnel Notes

(from page 67)

Robert R. Jay has been named manager of product marketing of the Transistor Division of the Sprague Electric Company, it was announced by Albert B. Dall, marketing manager. Mr. Jay was previously with General Electric Company where he was district sales manager for semiconductor products in the Long Island, New York area.

Anchor Alloys Inc., announced the appointment of Jerry G. Holecek, a research chemist and expert on polyester and epoxy resins, as director of newly established research facilities in the company's plant at 968 Meeker Avenue, Brooklyn. Primary objective of the department in exploring plastics technology is the manufacture and marketing of compounds based on resins and polysulphides, according to Herbert Drapkin, president.

Guy W. Wilson has been named regional sales manager for the Industrial Products group of Texas Instruments Incorporated, O. F. Henning, marketing manager, announces. Mr. Wilson will be in charge of the group's Mid-America region with headquarters in Chicago. He has been with TI for four years and was formerly a district sales engineer for the company in Cleveland and Chicago.

Alfred J. Giradot, Jr., formerly marketing manager for the Evanston, Ill., facilities of the Semiconductor Division of Hoffman Electronics Corporation, has been promoted to director of marketing for the entire division, T. S. Hoffman, vice president and division manager, announced. Previously, Mr. Girardot was in marketing for three years with Texas Instruments Incorporated, at Dallas, where his last position was product marketing manager for silicon controlled rectifiers in the Semiconductor Components Division.

Lester Avnet, president of Avnet Electronics Corporation, announced that Donald A. Davis has been appointed assistant to the president. Mr. Davis has long been associated with the electronics and aeronautics industries. He was previously with Cannon Electric Company for 19 years. Mr. Davis will make his headquarters at Avnet's executive offices in Westbury, Long Island.

Gordon L. Ness has been named to the new position of Instrumentation Marketing Manager for Fairchild Semiconductor. He will report to Thomas H. Bay, Director of Marketing. Mr. Ness previously supervised 20 west coast sales engineers on automation equipment and processes for Howe Scale, a Division of Fairbanks-Morse of Canada, Ltd.

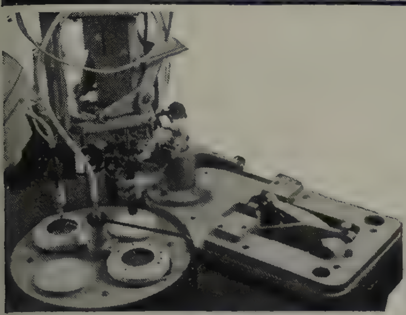
Dr. Maurice L. Torti has been promoted to the post of director of metallurgical research for the Metals Division of National Research Corporation. He is a graduate of Massachusetts Institute of Technology and has specialized in physical metallurgy, particularly in the development of vacuum melting, alloying and fabrication of refractory materials. Dr. Torti joined NRC in 1956.

INDEX TO ADVERTISERS

For reference purposes, the advertisers index includes all regular advertisers who have run within the current contract year. These advertisers who appear in this issue are indicated by the page number adjacent to their listing, and are shown in a bold-face type.

(Continued on page 71)

K&S NEWS



FOIL-DICE BONDER — Equipped with new automatic foil feed and indexing heat columns, machine positions and bonds both foil and dice on semiconductor headers. K&S Model 604 (not shown) available without foil feed.

K&S MODEL 604FF

for precision bonding of foil and dice

Inherent design of this precision equipment cuts time and cost, gives high output in positioning and bonding of foil and microcomponents to semiconductor headers.

- Carries foil of specified width and thickness; automatically feeds and cuts foil to exact pre-determined length
- In sequence, (1) picks up foil, (2) positions it on header, (3) picks up component, (4) positions it on foil, (5) bonds
- Positioning on header, heat and force of bonding hammer pre-set with positive controls
- Geneva movement rotary table, equipped with 2 heat columns and 2 component trays, operates on planned cycle of 10 to 20 seconds
- Entire operation under constant visual control (B&L Stereo-Zoom microscope optional) and protected by cover of forming gas

For additional information about K&S equipment — including probes, scribers, dice mounters, wire bonders, micropositioners and microcircuit machines — *write or call . . .*

KULICKE and SOFFA
MANUFACTURING CO. INC.

Pioneer Designers and Builders of Equipment for the Semiconductor and Microcircuit Industries

401 NORTH BROAD ST.
PHILADELPHIA 8, PA.
WAlnut 5-4270
Direct Distance Dial Code: 215

Circle No. 50 on Reader Service Card

INDEX TO ADVERTISERS

(Continued)

(Continued on page 72)

LOOKING FOR RELAYS?
Turn to section 4500

eem — ELECTRONIC ENGINEERS MASTER

Lepel

HIGH FREQUENCY *Induction* HEATING UNITS

HARDENING · ANNEALING
ZONE REFINING · CRYSTAL GROWING
SOLDERING · BRAZING

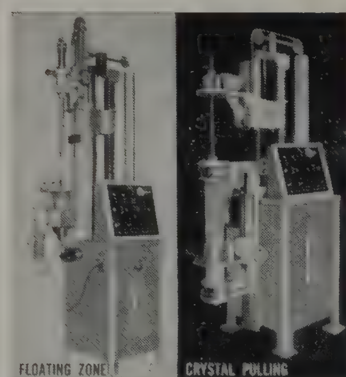
Lepel induction heating equipment is the most practical and efficient source of heat developed for numerous industrial applications

DUAL PURPOSE FLOATING ZONE AND CRYSTAL PULLING FIXTURE

A new fixture with separate attachments for crystal pulling and floating zone applications for use with a high frequency induction heating generator.

THE FLOATING ZONE METHOD is used extensively for zone refining and for growing crystals of high purity silicon for semiconductor devices by traversing a narrow molten zone along the length of the process bar in a controlled atmosphere.

THE CRYSTAL PULLING METHOD is used for growing single crystals of various materials, especially germanium, by bringing a seed of known crystal orientation into contact with the surface of the molten metal and slowly withdrawing the seed, producing progressive crystallization.



The Lepel Model HCP-D consists of the basic unit with the traverse mechanism and all the controls including the controls for the operation of the generator, and the floating zone and crystal pulling attachments. The same basic support, programming and control unit is used in either adaptation. The major variations are in the attachments and the induction coils. The change from one application to the other can be accomplished in a very short time.

Our engineers will process your work samples and return the completed job with full data and recommendations without cost or obligation.

WRITE FOR NEW LEPEL CATALOG

Lepel HIGH FREQUENCY LABORATORIES, INC.
55th ST. & 37th AVE., WOODSIDE 77, N. Y.
CHICAGO OFFICE: 6246 WEST NORTH AVE.

Circle No. 51 on Reader Service Card

INDEX TO ADVERTISERS

(Continued)

BE SURE TO

SEE READER SERVICE CARD

FACING INSIDE

FRONT COVER

SUBSCRIPTION ORDER BLANK

SUBSCRIPTION ORDER

U.S.A., POSS. A.P.O., F.P.O.	ALL OTHER COUNTRIES
☐ 12 Issues $ 6.00	☐ $10.00
☐ 24 Issues 10.00	☐ 18.00
☐ 36 Issues 13.00	☐ 25.00

☐ Remittance herewith ☐ Send Invoice

irs: Please enter my subscription to SEMICONDUCTOR PRODUCTS for . . . . issues

☐ New Subscription ☐ Renewal Subscription

PLEASE PRINT CAREFULLY—ANSWER ALL QUESTIONS

Name . . . . Position . . . .

Company . . . . Dept. . . . .

Address . . . .

City . . . . Zone . . . State . . . .

Products Mfd. . . . .

Please Send My Magazine to (If some other address):

Address . . . .

City . . . . Zone . . . State

For Further

Information On

THE DIODE SOURCE BOOK

See Page 18

of This Issue

No Postage Stamp Necessary If Mailed in the United States

BUSINESS REPLY CARD
FIRST CLASS PERMIT NO. 36540, NEW YORK, N. Y.

SEMICONDUCTOR PRODUCTS
300 WEST 43rd STREET
NEW YORK 36, N. Y.

Postage Will Be Paid by Addressee

MILGRAY DELIVERS SEMICONDUCTOR PRODUC FROM THESE MANUFACTURERS OVERNIGHT...ANYWHERE

BENDIX
COLUMBUS
ERIE
GEMCO
GENERAL ELECTRIC
GENERAL INSTRUMENT
GENERAL TRANSISTOR
HOFFMAN
KEMTRON
MICROWAVE ASSOCIATES
MOTOROLA
NATIONAL SEMICONDUCTOR
OHMITE
PHILCO
SARKES-TARZIAN
SPRAGUE
TUNG-SOL
TEXAS INSTRUMENTS
UNITED COMPONENTS
WESTERN TRANSISTOR
WESTINGHOUSE

MILGRAY/NEW YORK 136 Liberty Street/New York C
REctor 2-4400

COMPLETE SPECIFICATIONS: MAIL POST CARD BELOW

FIRST CLASS
PERMIT NO. 18
NEW YORK, NEW Y

BUSINESS REPLY MAIL

MILGRAY—NEW YORK—136 LIBERTY STREET, NEW YORK 6

A SIGNIFICANT BREAK-THROUGH IN TRANSISTOR TECHNOLOGY...

ECDC*

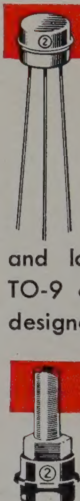
ELECTRO- CHEMICAL DIFFUSED COLLECTOR

The Best High-Power, High-Speed Switching Transistors Ever Developed Provide the Optimum Combination of Voltage, Power, and Speed

The Sprague ECDC Transistor is the first to combine the optimum features of the electro-chemical precision-etch techniques and diffused collector techniques in one highly-mechanized process.

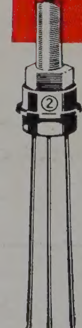
The ECDC Transistor meets these 7 conditions for an "ideal" transistor:

1. Very low collector-to-case thermal resistance through the utilization of high thermal conductivity material as the collector body, resulting in high power dissipation.
2. Thin base width for high radiation resistance and lower storage time.
3. Precision-etched emitter pit permits placement of emitter junction at proper resistivity for optimum breakdown voltage and frequency response.
4. High conductivity surface surrounds emitter pit and close emitter-to-base spacing results in extremely low base resistance.
5. Precision-etched collector provides optimum control of collector series resistance with attendant low saturation voltage, low storage time, and high breakdown voltage.
6. Low collector series resistance as a result of the use of high conductivity material for the mass of the collector area.
7. The structure and manufacturing processes are suited for automated production equipment with immediate in-process feedback.



TYPES 2N2099 & 2N2100

These P-N-P Germanium Electro-Chemical Diffused-Collector Transistors are especially designed for high current core driver applications. They feature excellent beta linearity from less than 1 ma to over 400 ma, high frequency response and low saturation resistance. The low-height TO-9 case is ideally suited to meet equipment designers' needs.



TYPES 2N2096 & 2N2097

Types 2N2096 and 2N2097 are electrically identical to Types 2N2099 and 2N2100 respectively, except for their TO-31 Case with its threaded stud mounting.

For complete information on ECDC Transistors, write Product Marketing Section, Transistor Division, Sprague Electric Company, Concord, New Hampshire.

*Trademark of Sprague Electric Co.

SPRAGUE COMPONENTS

TRANSISTORS	INTERFERENCE FILTERS	HIGH TEMPERATURE MAGNET WIRE
CAPACITORS	PULSE TRANSFORMERS	CERAMIC-BASE PRINTED NETWORKS
MAGNETIC COMPONENTS	PIEZOELECTRIC CERAMICS	PACKAGED COMPONENT ASSEMBLIES
RESISTORS	PULSE-FORMING NETWORKS	FUNCTIONAL DIGITAL CIRCUITS

SPRAGUE®
THE MARK OF RELIABILITY

Circle No. 3 on Reader Service Card